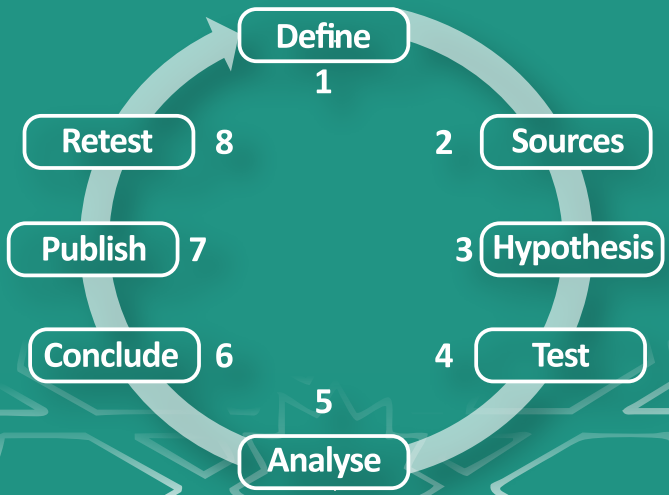
The Scientific Method
A Practical Guide



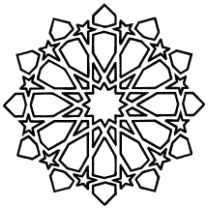
Michel BAKNI

2025

I dedicate this book to my people ...

the Syrians,

who bravely revolts, fought, suffered and triumphed against the most brutal dictator of our time ...



The Scientific Method

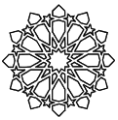
A Practical Guide

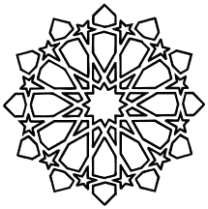
by

Michel BAKNI,
Ph.D.

2025

Orthez, France





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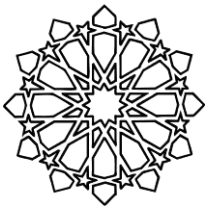

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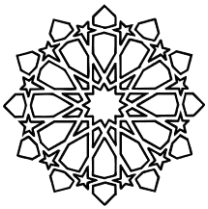

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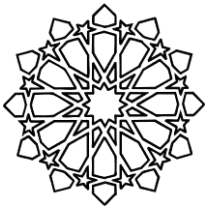

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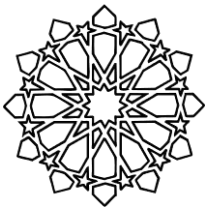

List of abbreviations

AI: Artificial Intelligence.

APA: American Psychological Association,

CMOS: Chicago Manual of Style

CNG: Classical Numismatic Group

CRU: Climatic Research Unit

CUDOS: Communism, Universalism, Disinterestedness, Organised Skepticism

DOI: Digital Object Identifier

EU: European Union

FFP: Fabrication, Falsification, and Plagiarism

GDPR: General Data Protection Regulation

GMC :General Medical Council

GPS: Global Positioning System

HIPAA: Health Insurance Portability and Accountability

IRB: Institutional Review Board

IRENA: International Renewable Energy Agency

ISBN: International Standard Book Number

ISNI: International Standard Name Identifier

ISO: International Organisation for Standardisation.

ISSN: International Standard Serial Number.

MLA: Modern Language Association

MMR: measles, mumps, and rubella

MPS: Master of Professional Studies

OCLC: Online Computer Library Centre

Ph.D.: Doctor of Philosophy

PD: the Public Domain

UEA: University of East Anglia.

UFO: Unidentified Flying Object

UK: United Kingdom

URL: Uniform Resource Locator

US: United States

VIAF: Virtual International Authority File

WWII: World War 2

WWW: World Wide Web

Introduction

Research has undoubtedly been a driving force in shaping human civilisation over the past few centuries. When applied scientifically, the research process uncovers natural laws that allows to predict changes in the physical world with remarkable accuracy. However, research is not confined to the study of nature, it is also widely utilised in social sciences. While outcomes in this field are often less definitive, research contributes significantly to enhance understanding of human behaviour, societal structures, and development.

Although research is grounded in scientific methods, the term “scientific” can sometimes seem ambiguous. What truly drives the success of research is the adherence to a systematic process, a set of well-defined steps that must be strictly followed. For this reason, the term “systematic” may more accurately describe the essence of research.

The systematic nature of research introduces complexities that often limit its accessibility. In the modern world, research findings are frequently challenged by political figures using weak or overly simplistic arguments. Unfortunately, these arguments often resonate with the public, leading to widespread scepticism towards science and easy political victories.

Humans, as individuals, are not naturally inclined towards logic, it is a skill acquired through education and practice. In everyday life, people often rely on instinct and make quick decisions without a solid foundation. This tendency can weaken the public's ability to appreciate research findings, despite their well-structured and evidence-based nature.

This challenge, faced by research, was the main motivation behind creating this work. The book is designed as a straightforward and concise guide to research, carefully prepared for postgraduate students starting their research journey. However, it

is equally suitable for anyone seeking to understand the nature of science and the structure of research.

Why I am writing this book and what qualifies me?

Research has always been an integral part of my daily life. As a specialist in applied science with a Ph.D. in electronics, I work as a research engineer in higher education. My role involves conducting research for both academia and industry while also teaching and mentoring students.

During my academic journey, I had the opportunity to guide engineering students from Jiangsu University as part of a student exchange programme at ESTIA institute of technology. Over four years, I taught these students research methodology, supervised their final graduation projects, and helped them write research theses. This experience gave me a profound understanding of what students need to transition from merely receiving knowledge to creating and discovering during their final stage of their studies.

In addition to my academic responsibilities, I received a grant[1] from the Wikimedia Foundation to develop a learning module on the scientific method. This module aimed to enhance the contributions of Wikipedia editors by aligning their work with scientific principles. Teaching approximately 50 Arabic Wikipedia editors from diverse backgrounds, ranging from high school students to retirees, was a challenging yet rewarding experience.[2] It helped me better understand the gap between researchers and non-researchers and taught me how to simplify methods and concepts for people outside the academic sphere.

In recent years, I have deliberately worked with researchers from various fields to explore research methods beyond the inductive approach, typical in applied sciences, my primary domain. This journey

[1] Check the grant page for more details: https://w.wiki/6BeP.
[2] A MOOC was developed as a result, check the MOOC page for more details: https://w.wiki/7HUD.

allowed me to practice descriptive research methods in history[3] and deductive methods in law[4], broadening my understanding of diverse research methods.

These varied experiences in practicing and teaching research have equipped me with a comprehensive perspective. I have gained a solid foundation in how to approach research, how to present it to new researchers, and how to help individuals take their first steps into this domain.

[3] Refer to "Osman I, father of kings" published in WikiJournal of Humanities in 2021. Mainly Authored by Bassem FLEIFEL. DOI: 10.15347/WJH/2021.001, URL: https://w.wiki/wiT.

[4] Refer to the articles: "Dual Higher Education in Belgium: Legal Framework, Application and Educational Paths" DOI: 10.25162/EJDHE-2024-0004, and "Dual Higher Education in Luxembourg: Legal Framework, Application and Educational Paths", DOI: 10.25162/EJDHE-2024-0007. Both mainly authored by Anna DUPOUY.

Structure of the book

The primary goal of this book is to serve as a practical, accessible guide for early-carrier researchers taking their first steps into the world of research. It is not designed as a specialised or intensive guide for any particular research field.

For this reason, the content focuses on common elements shared across research domains, such as defining the research problem and writing the final report. In contrast, it only briefly touches on aspects that vary between disciplines, such as designing experiments or analysing results. Each of these specialised phases is a complex subject on its own, requiring domain-specific treatment. Covering them in a single book would compromise its broad applicability.

The book is structured into two main parts. Part I explores the foundations of the scientific method, including its historical origins, key principles, and overall structure. Part II focuses on the practical

aspects of research, such as formulating research questions and scientific writing.

Part I includes four chapters:

- **Chapter 1** defines knowledge by exploring its types, characteristics, how it is created, and how to describe a piece of it. It also provides a brief introduction to historical figures who contributed to shaping humanity's understanding of science and knowledge.
- **Chapter 2** focuses on facts, explaining how people use knowledge to create both simple and complex facts. It highlights that facts are not always valid, especially when they are not established through a solid method.
- **Chapter 3** introduces the research method as a structured approach to generating scientific facts. It clarifies the distinction between method and

methodology and explains different types of research methods, including descriptive, deductive, and inductive approaches.

- **Chapter 4** explores the scientific method as a specific type of research method, presenting it as a continuous eight-step process. Each step is explained in detail, along with a discussion of the key properties that define the scientific method.

Part II includes four chapters:

- **Chapter 5** focuses on identifying, defining, and describing a research problem scientifically. This is the first and most challenging step in the scientific method. Therefore, early-carrier researchers often need guidance from senior researchers to navigate this stage effectively.

- **Chapter 6** is dedicated to the sources used in developing a research problem. It explains what qualifies as an acceptable source in the research domain, how to search for reliable information efficiently using selective reading, and how to organise acquired knowledge systematically. This ensures that all references remain traceable to their original sources whenever needed.
- **Chapter 7** explores research ethics, why they exist, where they originate, and their role in maintaining integrity in research. The chapter includes real-world examples that highlight the importance of ethical considerations in academia and industry. Additionally, it provides a set of recommendations to help researchers avoid unintentional ethical violations.

- **Chapter 8** introduces scientific writing and publication, covering best practices for maintaining a straightforward and precise scientific style. It discusses essential elements such as wording, figures, and tables while also outlining the various scientific outputs that research can generate.

The reference section is the final part of the book and is organised into four main categories: articles (AR), books (BK), theses (THS), and web sources (WEB). Each category is arranged in the order of citation as it appears in the book.

To further streamline the references, articles and books are classified by language using specific letter identifiers: A for Arabic, E for English, F for French, G for German, and L for Latin.

For example, a reference labelled [BKE15] indicates the fifteenth entry in the English books category,

while [ARG01] represents the first reference in the German articles category.

Acknowledgements

This book would not have been possible without the support and encouragement of many individuals. Writing this book is no easy task, and countless colleagues have, often indirectly or even unknowingly, influenced the process of creating it. I extend my gratitude to those mentioned below, regardless of the order in which they appear.

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- I would also like to thank my Ph.D. supervisor, Dr. Octavian CUREA, from whom I learned not only how to conduct research but also the importance of precision and critical thinking. His guidance and mentorship shaped my approach to academic work, teaching me to look beyond the surface and seek a deeper understanding of the reasons behind what we observe.
- I extend my sincere thanks my friends in the Arabic Wikipedia community, especially Dr. Bassem FLEIFEL, Dr. Alaa NAJJAR, and Ahmed Nagy ABOUELASAAD, who generously contributed their time to engage in discussions and help develop ideas that are now integrated throughout the chapters of this book. Their dedication to knowledge-sharing and collaboration has been truly inspiring.

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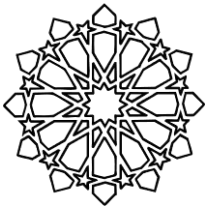


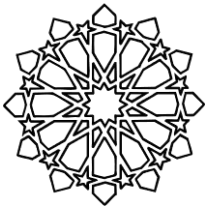
PART I: Foundations of the scientific method

Ch. 1 Knowledge & its types

Ch. 3 Scientific facts

Ch. 2 Research methodology

Ch. 4 Scientific method



Knowledge & its types

Introduction

What is knowledge? A challenging question to begin with. The difficulty lies in the fact that, to accurately define a concept or idea, one must already have a deep understanding of it. Therefore, having knowledge about the subject being studied is crucial to forming a clear and precise definition, even when that subject is knowledge itself.

Knowledge has shaped human society throughout history. In the prehistoric era, knowledge was transmitted orally through storytelling until the invention of writing, which allowed for the documentation of knowledge in the form of myths and religious texts. Thousands of years later, in classical antiquity, ancient Greece made the first significant efforts to explore the nature of knowledge, and philosophy was created as a result. During the Middle Ages, known as the Age of Faith,

knowledge played a crucial role in both Christian and Islamic worlds, but in different ways. In Europe, the Church controlled knowledge, creating a small, literate class and ushering in the so-called “Dark Ages”. Meanwhile, in the Islamic world, knowledge was widely valued and pursued, leading to what is now known as the Islamic Golden Age.

As time progressed, the pursuit of knowledge became the driving force behind the Renaissance and Enlightenment ages in Europe, leading to a more accessible education system beyond the Church’s control. This laid the foundation for the scientific revolution, which emerged as a global force and profoundly influenced the modern era. The history of knowledge is the history of humankind.

This chapter explores the nature of knowledge and offers an overview of the history of science. It examines the relationship between science and knowledge, and how this connection influences modern definitions of knowledge.

Nature of knowledge

To establish a solid foundation, the first step is to define what knowledge is. However, dealing with abstract and unquantified concepts, like knowledge, is not simple. As the discussion in the book advances, similar challenges will inevitably emerge. Therefore, before proceeding, it is crucial to outline how to approach these complex ideas with the aim of forming clear definitions.

Defining a concept involves several steps:

1. Identify the key term and review its definitions in standard dictionaries.
2. Examine the etymology[1] of the term of the word.
3. Develop a definition of the concept using the knowledge gained from the previous steps.

[1] Etymology is the study of the origins and development of words. It is a branch of linguistics that examines how words evolve over time, their sources, and their connections to other words in the language.

With all that in hand, the starting point is knowledge.

After completing the first step, the following definitions have been gathered. The first definition, obtained from the Oxford Learner's Dictionaries[2], is:

> *"Knowledge is the information understandings and skills that you gain through education or experience."*

The second dictionary is the Cambridge Dictionary, it reads:[3]

[2] Hereafter, "Oxford Learner's Dictionaries" will refer to the 10th edition of the Oxford Advanced Learner's Dictionary of Current English, published in 2023 by Oxford University Press. Full bibliographical details are provided in [BKE01].

[3] Hereafter, "Cambridge Dictionary" will refer to the 4th edition of Cambridge Advanced Learner's Dictionary, published in 2013 by Cambridge University Press. Full bibliographical details are provided in [BKE02].

"Knowledge is information and facts about something you know."

The last dictionary is Merriam Webster Dictionary[4]. In this dictionary the knowledge is defined as follows:

"It is the fact or condition of knowing something with familiarity gained through experience or association."

It should be noted that these definitions are closer to common sense than to a solid definition.

However, some shared terms can be identified:

- Both Oxford and Cambridge dictionaries include the term "information".

[4] Hereafter, "Merriam Webster Dictionary" will refer to the revised edition of The Merriam-Webster dictionary, published in 2013 Merriam-Webster, Inc. Full bibliographical details are provided in [BKE03].

- Cambridge and Merriam-Webster both use the term “fact”.
- Oxford First and Merriam-Webster share the term “experience”.

Next, the etymology[5] of the word “knowledge” reveals its origins in Old English, dating back to the early 12th century, where it meant “to be able to distinguish”. The word is composed of two parts: “know” and “ledge”.

The first part of the word traces back to the proto-indo-european root “gno-” meaning “to know”. The origin of the second part, however, remains unknown. With current linguistic knowledge, its exact origin cannot be determined.

The suffix “gno-” appears in other English words like agnostic, ignorant, and recognise. In each of these

[5] Hereafter, etymology is based on the 2ed edition of the Oxford English dictionary, published in 1989 by Oxford University Press. Full bibliographical details are provided in [BKE04].

words, the meaning of “to know” or “to distinguish between two things or concepts” is evident.

The third step is to define the concept, in this case: “knowledge”. Scientists and philosophers today have significant disagreements about what constitutes “knowledge”. It is generally accepted that there is no consensus on its precise meaning. Some philosophers even argue that true “knowledge” might not exist at all. Thus, unfortunately, there is no exact definition.

How can this problem be addressed? Why is it so challenging to define a concept that is frequently used in daily life?

The difficulty comes from the fact that the word “knowledge” has three different meanings:

1. The first type is theoretical knowledge, also known as “know-that knowledge”. For example, knowing that World War II ended in 1945 is an example of this type of knowledge.

2. The second type is practical knowledge, referred to as “know-how knowledge”. For instance, knowing how to cook or play football falls into this category.
3. The third type is personal knowledge, which comes from personal experience and relationships. For example, stating that Lionel Messi[6] is the greatest football player of all time is a form of personal knowledge based on individual opinions and personal judgments.

The difference between theoretical and personal knowledge is that theoretical knowledge is likely to be consistent among people. For instance, almost everyone agrees that World War II ended in 1945. In contrast, personal knowledge varies widely. For example, asking who is the greatest football player of

[6] Lionel Andrés Messi (1987-) an Argentine professional footballer, widely regarded as one of the greatest football players of all time.

all time will yield many different answers, none of which can be definitively proven valid or invalid. These answers are based on individual opinions and interpretations.

Due to the various types of knowledge and the different meanings of the term, defining "knowledge" is a complex task. Despite advances in technology, a universally accepted definition of knowledge remains elusive.

Sources of knowledge

Knowledge is obtainable. At birth, a human has no knowledge, neither theoretical, practical, nor personal.

There are four main sources of knowledge: indoctrination, observation, experimentation, and reasoning. The following section will briefly cover these sources, focusing on the challenges associated with each.

Indoctrination

Indoctrination can be a source of all types of knowledge. It occurs when people get ideas, attitudes, and information by listening to each other.

Indoctrination is completely based on imitating others, repeating what they are doing, or believing what they have said without any intent to understand the underlying reasons or methods.

For instance, accepting information simply because it was stated, like believing that Napoleon[7] invaded Egypt in 1798 or that Canada is north of the United States, are examples of indoctrination. This concept can extend to various behaviours, especially when followed without question, such as wearing certain clothing, adhering to specific diets, or participating in religious rituals.

[7] Napoleon Bonaparte (1769–1821), also known as Napoleon I, was a French military officer who rose to prominence following the French Revolution. He declared himself Emperor of the French from 1804 to 1814. Bonaparte is regarded as one of the greatest military commanders in history.

Indoctrination comes with several issues:

- It can be false. For example, no one alive today witnessed Napoleon invading Egypt, so this could be just misinformation.
- It can be inaccurate. In the case of Napoleon's expansion, the date is given only as a year, with no specific month or day. This lack of detail limits the ability to further develop or refine the information.
- It can be fictional. For instance, stating that Frodo Baggins[8] destroyed the One Ring at Mount Doom in Mordor is a true piece of information, but it is completely fictional.
- It is difficult to verify. For example, how can one prove that Napoleon really existed while Frodo Baggins did not?[9]

[8] Frodo Baggins is one of the main characters in J.R.R. Tolkien trilogy: The Lord of the Rings.

[9] Historians use a specific approach called the Historical Method, which will be discussed in Chapter 3. The challenge with this method is that it requires specialised skills. Those who lack =

- It can be manipulated. The spread of conspiracy theories related to COVID-19 illustrates how information can be distorted when its source is indoctrination.

Observation

Observation involves using the senses, such as seeing and hearing, to identify patterns in natural phenomena.

This process can also apply to human phenomena. For instance, before the Renaissance, knowledge about the stars was based entirely on observation. People observed the night sky over generations and recorded their findings. They identified patterns in the stars, which were crucial for various applications. For example, sailors in antiquity and the Middle Ages used these patterns to navigate by determining directions based on the positions of stars.

= these skills, including non-specialists or those without sufficient experience, may find it difficult to use or may not fully understand how it works.

Another example involves civilisations located near rivers. People in these areas observed the river's flow patterns at different times of the year, which helped them determine the agricultural seasons and plan their activities accordingly.

The primary aspect of this source is its personal nature; this means that two individuals observing the same phenomenon may see different aspects or interpret the same observation in varying ways.

Another characteristic of observation is independence. This means that observers should not interfere with the phenomenon they are studying. They need to observe from a distance without affecting or altering the phenomenon in any way. If observers intervene, control, or modify the phenomenon, it is no longer a true observation.

Observation also has several limitations:

- It relies entirely on the senses, which can be deceived.

- It is subjective, meaning that personal biases can affect the accuracy of the observations and notes taken.
- It can be risky. For example, observing a volcano closely can be dangerous due to the extreme heat and toxic gases associated with such phenomena.

Experimentation

Experimentation is the third source of knowledge. It involves identifying patterns in phenomena created by humans, using both senses and instruments. Since these phenomena are human-made, observers know precisely when and how they will occur, allowing them to be well-prepared and use devices to measure various aspects accurately. Thus, experimentation relies on both sensory observation and precise instruments. Examples of experiments range widely, from a teacher conducting a chemistry experiment in a high school class to government tests assessing the strength of nuclear weapons.

In experimentation, the observer actively engages in the process, unlike observation, where the observer remains passive.

A key characteristic of experimentation is repeatability, which means that an experiment can be conducted as many times as necessary. This repeatability is due to the controlled and human-made nature of the experiment.

Experimentation is also associated with several challenges:

- Preparation is required. Before conducting an experiment, it is necessary to determine what to measure, how to measure it, and which instruments to use.
- It is personal experience. Thus, it can be biased. Similar to observation, if the

experimenter has biases, these can influence the results.[10]

- It has moral aspects. Especially when it affects humans, animals, or the environment. Ethical responsibilities must be upheld: for human subjects, their rights must be respected throughout the process. For animals, experiments should avoid unnecessary suffering, adhering to guidelines that prevent pain and require euthanasia if the tests cause permanent damage. And for the environment, experiments like nuclear tests should consider their long-term impact, pollution and ecosystem destruction. These moral aspects must be integrated into the planning and execution of any experiment.[11]

[10] Bias can be minimised, or even removed, by following a clear and detailed method. This topic will be explored in depth later in the book.

[11] The ethical aspects of research will be addressed in Chapter 7 of the book.

Observation and experimentation share several similarities and differences. The following comparison will examine these two methods based on the criteria of perception, neutrality, human involvement, repeatability, and verifiability.

Perception refers to how knowledge is acquired and what tools or methods are used. Neutrality addresses the role of the observer in the knowledge-gathering process. The human role criterion examines how individuals influence the acquisition of knowledge. Repeatability assesses whether the process can be replicated to obtain the same results. The final criterion evaluates the ability to verify the knowledge obtained.

Table 1-1 presents a comparison between observation and experimentation. In terms of perception, both methods use sensory input and tools. Knowledge is gained and understood through the senses, with devices aiding in the process.

Ultimately, senses are essential to read the written results.

Regarding neutrality, both observation and experimentation can be subject to bias, as both methods involve human participation, and humans can introduce biases, which can affect both the process and the results.

In terms of repeatability, naturally occurring phenomena generally cannot be repeated exactly. For example, while a river may flood annually, it is not feasible to replicate the flooding precisely for repeated observations. Conversely, experiments are repeatable because they are human-designed. Since the phenomenon is created by humans, it can be replicated to measure different aspects consistently.

Finally, regarding verifiability: knowledge gained from observation is often difficult to verify because the observed scenario cannot be recreated to check all possible parameters. In contrast, knowledge from experiments is easier to verify because experiments

involve human-created phenomena that can be repeated to check and confirm all relevant parameters. Therefore, knowledge obtained from experiments is generally more reliable than knowledge obtained from observation.

Table 1-1. Comparison between Observation and Experimentation

Criteria	Observation	Experimentation
Perception	Sensory & tools	
Neutrality	Might be biased	
Human role	Passive	Active
Repeatability	Non-repeatable but can be periodic	Repeatable
Verifiability	Possible, with complexity	Possible

Reasoning

The fourth source of knowledge is reasoning, which involves using logic consciously to draw conclusions and acquire knowledge.

Reasoning is purely mental and does not require tools or sensory input. While reasoning aims to produce new knowledge, the conclusions can be valid, but they may also be false or corrupted.

Here are two examples of reasoning. Consider the following statements:

a. All French people speak French.
b. Francois is a French.

From these two statements, the following conclusion can be drawn:

"Francois speaks French"

The second example include the following statements:

a. Aluminium expands with heat.
b. Iron expands by heat, and
c. Aluminium and Iron are metals.

From these three statements, the conclusion can be drawn:

"Metals expand with heat"

In the first example, the initial statement provides a general case, while the conclusion represents a specific case. In contrast, the second example starts with specific cases or instances and draws a conclusion that applies to the general case or the entire category.

Reasoning can be classified into two main types: deductive and inductive. The first example illustrates deductive reasoning, which emphasises specificity. In deductive reasoning, one starts with general statements and aims to draw conclusions about specific cases. Conversely, the second example demonstrates inductive reasoning, which focuses on generalisation. Inductive reasoning begins with specific instances and aims to form general conclusions that apply to a broader category.

Here are two additional examples to clarify the difference. In the third example, the first statement:

a. In every triangle, the total of all three angles is 180 degrees.[12]
b. ABC is a triangle.

From these two statements, deductively, it can be concluded that:

"The sum of ABC angles is 180"

The starting point addresses the whole, and through deductive reasoning, the conclusion is drawn to apply to a specific case.

In the fourth example, a box contains 50 balls that are identical in all aspects except for their colours: black and white. The exact number of each colour is unknown.

[12] This statement is only valid in Euclidean geometry and does not apply to other geometries, namely elliptic and hyperbolic.

Ten balls are drawn, resulting in eight black and two white. Although not all 50 balls are drawn, a generalisation is made from this sample:

"80% of balls in this box are black and 20% are white"

The process begins with specific parts and extends to a general conclusion.

Reasoning, however, has its challenges:

- It requires skill and training to be used effectively. Unlike common sense, reasoning relies entirely on logic, which can only be developed through practice.

- It can be misleading. If not applied carefully, reasoning can lead to fallacies,[13] where corrupted knowledge will be created.

Aspects of knowledge

Knowledge is difficult to define due to its complexity. It encompasses multiple dimensions that cannot be fully captured by simple yes or no logic. Instead, a spectrum[14] is required to accurately describe each of its aspects.

Knowledge involves five aspects: credibility, level of details, complexity, degree of abundance, and the skills needed to understand or use it. Figure 1-1 shows how aspects can be presented using spectrums.

[13] Also known as paralogia, this term refers to the use of faulty reasoning to build a false argument that may seem logically sound.

[14] In this context, "spectrum" refers to a range where values are distributed on a continuous decimal scale.

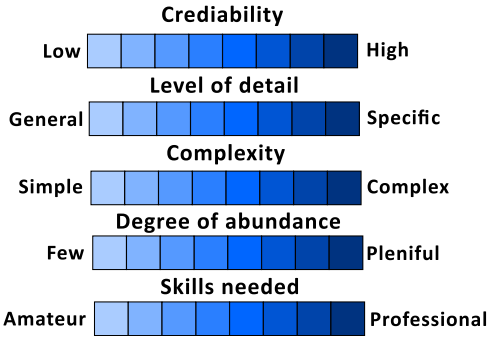


Figure 1-1. Aspects of the knowledge

Concerning credibility, this refers to how trustworthy a piece of information is. It can vary from low to high, with intermediate levels in between.

The level of detail describes how specific the information is. It can range from general to specific, with various degrees of specificity in between.

Complexity refers to how sophisticated the information is. Is it easy to understand, or does it require breaking down into smaller parts to be comprehended? Knowledge can be simple, complex, or somewhere in between.

The degree of abundance pertains to a set of information rather than a single piece. It addresses

how comprehensive the set is and whether there is repetition within it. The spectrum ranges from few knowledge to plentiful.

Finally, the skill required to understand or use the information involves assessing whether expertise is needed. The spectrum for this aspect ranges from basic understanding to professional expertise, with varying levels in between.

Figure 1-2 illustrates how to represent a piece of information using a RADAR diagram. This diagram is pentagon-shaped, with each vertex representing one aspect of knowledge. The lines connecting each vertex to the centre of the polygon are called radii, and they are scaled from 1 to 10. A higher value indicates a greater influence of the aspect it represents, while a lower value suggests a lesser influence. For example, in the RADAR diagram shown in Figure 1-2, the information has a skill needed rated at 9, credibility at 7, level of detail at 4, complexity at 5, and degree of abundance at 3.

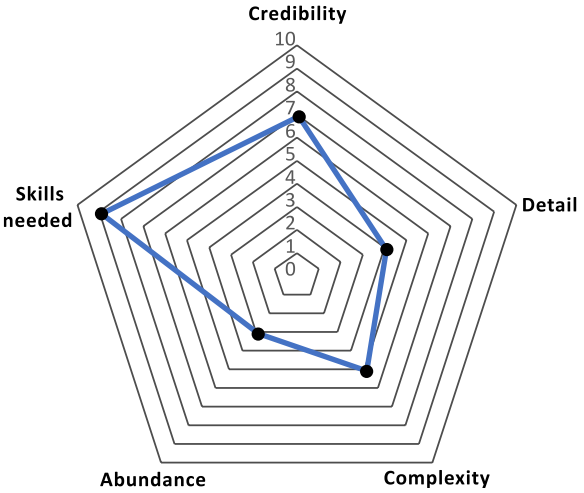


Figure 1-2. RADAR diagram

The advantage of the RADAR diagram is that its axes are independent of each other. This means that a piece of information can have a value of 10 on one aspect while having a value of zero on another aspect. This independence allows for a straightforward representation of varying values across different aspects.

Knowledge and science

This section will start by following the same steps outlined earlier in this chapter, conducting a search for the term “science” in various dictionaries.

To begin with, the Oxford Learner’s Dictionary defines “science” as follows:

“Knowledge about the structure and behaviour of the natural and physical world based on facts that you can prove for example by experiments the same injury”

In Cambridge Dictionary, it reads as follow:

“The study of the physical world by collecting information and testing it”

Finally, according to the Merriam-Webster Dictionary, the entry for “science” is as follow:

“Knowledge or a system of knowledge covering General truces, or the operation of the general laws especially as obtained and tested through scientific method”

In both the first and third definitions, the keyword “physical” is common. Science focuses on the physical world, which can be observed and measured. Another keyword, “test”, is shared between the second and third definitions. This concept will be explored further in this section.

In the second step, the focus will be on the origin of the word “science”. Its roots can be traced back to the mid-14th century, where it was used to mean “to know”. The word itself is derived from the proto-indo-european root “skei-”, which means to cut, split, or divide.

It is widely accepted among linguists that the original meaning of the word “science” is rooted in the idea of distinguishing what is known from what is not.

The same root also gave rise to other words that are still in use in modern English. For example, “conscience” refers to the inner sense or voice that guides a person in judging the rightness or wrongness of their actions. Another word is “schism,” which describes a division or split between opposing groups, often driven by differences in belief or opinion.

Given this information, the next question is: what is the precise definition of science?

Although multiple definitions exist, they generally agree on the core meaning but vary in expression. A comprehensive definition is provided by Edward Wilson in his book “Consilience: The Unity of Knowledge”; it reads:[15]

[15] See p. 53 in [BKE05]

"Science is the organised systemic enterprise that gathers knowledge about the world and condenses the knowledge into testable laws and principles"

In this definition, the terms "systematic" and "testable" are key elements. These characteristics of science will be examined in detail in the following.

Based on this definition, it is safe to conclude that not all knowledge is scientific. For knowledge to be deemed scientific, it must be developed in a systematic manner and be testable.

A systematic approach means that the method used to generate the knowledge is repeatable and typically follows a series of steps. Testable means that the method can be verified; others should be able to replicate the process under the same conditions and obtain consistent results.

To demonstrate these two properties, consider the following example (Figure 1-3): A large amphitheatre at a university is examined. Two individuals are positioned in front of it. A question is posed: “How many seats are there?”

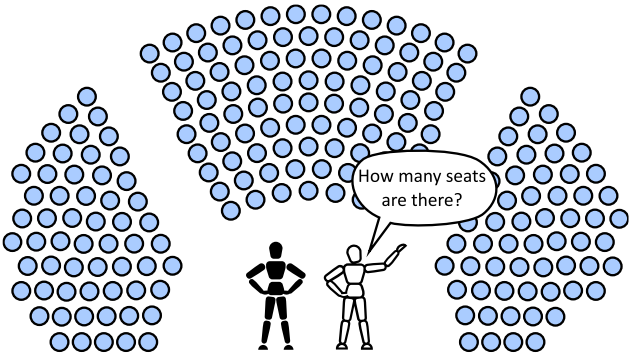


Figure 1-3. The amphitheatre scenario

If the response is that “Based on experience, it is estimated that there are 700 seats”, this answer lacks a systematic approach, as there is no clear explanation of how the number 700 was determined. Consequently, it is safe to conclude that the response, or the knowledge obtained, does not meet the criteria for scientific knowledge.

Conversely, if the response is: “Determine the number of rows and then multiply it by the number of seats per row”, the obtained knowledge is considered systematic. This approach provides a clear method for calculating the total number of seats. Additionally, it is testable; one can count the rows and seats, and then verify the result against the proposed calculation. Therefore, this method of obtaining knowledge is regarded as scientific.

This example demonstrates how science can refine and enhance knowledge. In this scenario, once the counting begins, an additional issue arises: the number of seats per row varies. As a result, using a multiplication method may yield low accuracy. Nevertheless, the method can be adapted to improve the accuracy of the findings.

This exemplifies how science operates: through the continuous refinement and enhancement of method. However, this raises a significant question: if scientific knowledge is always subject to change and

improvement, is the knowledge-based understanding of reality genuinely real?

To address this question, it is essential to define both reality and facts. Reality refers to what exists independently of the observer's awareness or perception. It remains true regardless of whether or not it is recognised by the observer. A pertinent example is radio waves. They have always existed, but they were undetectable by human senses for centuries. Despite their invisibility, radio waves are a part of reality.

However, as technology advanced, humans were able to improve their understanding of reality. Devices that could detect these previously invisible waves were developed. Additionally, Humans used these waves for their interests, and today, nearly all wireless communication systems rely on them.

In other words, scientific facts offer the best current understanding of reality. However, because this understanding is incomplete, scientific facts can be

inaccurate. They are not permanent but can change over time. As technology progresses, the scientific comprehension of the physical world is expected to become more precise and align more closely with reality.

Figure 1-4 illustrates the progression of human understanding regarding the Earth's shape over time and its connection to reality and scientific facts. Today, it is a scientific fact that the Earth is nearly spherical. This has always been the case, even when humans did not exist or were unable to comprehend this reality.

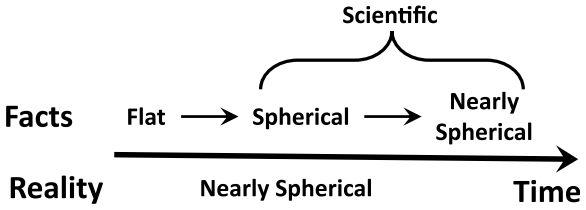


Figure 1-4. Earth's shape: Reality Vs. facts

On the other hand, human understanding of the Earth's shape has evolved over time:

1. Initially, it was believed that the Earth was flat. This belief was considered a fact for centuries, and many lost their lives in attempts to prove that this fact was invalid.
2. As humans progressed in time and technology, it became undeniable that the Earth was spherical, and for many years, this was the widely accepted fact.
3. Finally, with further advancements, humans were able not only to discover and measure the Earth's shape but also to see with their own eyes that it is nearly spherical.

At first, the belief that the Earth was flat was accepted as a fact, but it was not scientific because it could not be tested. In contrast, the facts that the Earth is spherical and nearly spherical are scientific. These facts are systematic and can be mathematically proven. They are also testable. For instance, telecommunication systems, such as the Global Positioning System (GPS), provide practical evidence

that the Earth is spherical and, more precisely, nearly spherical. If this were not the case, these systems would not function correctly, at least from a mathematical perspective. Further discussion on scientific facts will be developed in Chapter 2.

Historical background

The final section of Chapter 1 focuses on the history related to science and scientific thinking. Figure 1-5 presents a timeline with two key reference points. The earliest, around 3500 BCE, marks the estimated creation of the first writing system in human history. It is a significant milestone as knowledge could not be systematically stored before writing became possible. Prior to this date, knowledge primarily depended on memory, and due to the lack of written records before the invention of writing, the available knowledge from that period is minimal. The second reference point is the Renaissance, which began around 1500 CE.

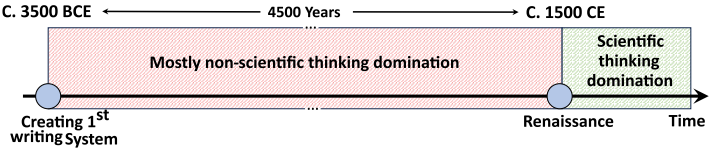


Figure1-5. Timeline of scientific and non-scientific thinking

Science, as it is understood today, began to take shape during the Renaissance, marking a significant point in human history.

However, this does not mean that scientists did not exist before this period. Throughout history, various civilisations, often separated by vast distances, made scientific attempts to explain natural events.

Unfortunately, these early efforts were not organised systematically; while there were brilliant individuals contributing to knowledge, science was confined to specific people or groups and had not yet evolved into a clearly defined method.

As Figure 1-5 illustrates, it can be reasonably assumed that non-scientific thinking prevailed during the first five thousand years of human history, whereas scientific thinking has become dominant in

the last 500 years. This period represents about 10 percent of recorded history, yet technological advancements during this time have far exceeded that proportion.

Science is crucial to technological advancement: non-scientific thinking focuses on the results, if something works, it does not matter how. In contrast, scientific thinking is primarily concerned with the method or technique used.

And here is an example that show the difference:

$$(a+b)^2 = a^2 + 2ab + b^2$$

This is a simple middle-school-level equation. From a non-scientific perspective, it may seem like nothing more than a series of symbols put together, with no practical application. However, from a scientific standpoint, this equation is a tool: anyone can substitute values for a and b and obtain clear, precise results.

What is seen as basic knowledge today was unimaginable 700 years ago. Although this transformation took centuries of gradual progress, several key contributions stand out and will be highlighted in the remainder of this chapter.

Ibn Al-Haytham (965-1040)

The first figure to introduce is Al-Hasan, also known as Ibn Al-Haytham in Arabic. Al-Hasan was a pioneer in developing scientific methods.

He lived in the 10th century, residing in Basra and Cairo, which are in present-day Iraq and Egypt, respectively. At that time, Islamic civilisation was at its peak. Although Al-Hasan was involved in the Fatimid Caliphate, he is best known for his contributions to optics rather than politics. He discovered the basic principle of photography. In fact, the word "camera" originates from the Arabic word "Qumrah" meaning chamber or room.[16] In this

[16] The original Arabic word is "قُمْرة".

chamber, designed by Al-Hasan, light was captured and treated as the source of the image.

Figure 1-6. Imaginary drawing for Ibn Al-Haytham [17]

Al-Hasan is widely recognised as the first individual to describe the scientific method. During the 10th century, a period known as the Age of Faith[18], it was unusual to encourage people to question their

[17] This image is taken from the Iraqi 10 Dinars banknote issued by the Central Bank of Iraq in 1981.

[18] Will and Ariel Durant used this phrase as the title for the fifth volume of their history series, "The Story of Civilisation". This volume was published in the USA by Simon & Schuster in 1950.

established knowledge as a means of verification. In that era, Al-Hasan wrote:[19]

"The duty of the man who investigates the writings of the scientists if learning the truth is his goal is to make himself an enemy of all that he reads he should attack what he reads from every side he should also suspect himself as he performed his Critical examination of it so that he may avoid failing into either Prejudice or leniency"

Francis Bacon (1561-1626)

Moving ahead five centuries to the Renaissance period, the next figure to be introduced is Francis Bacon, the Lord High Chancellor of England (Figure 1-7).

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[19] This is quoted from the original Arabic book: Doubts Concerning Ptolemy, Al-Shukūk ʿalā Batlamyūs =على الشكوك بطليموس, see p. 3-4 in [BKA01].

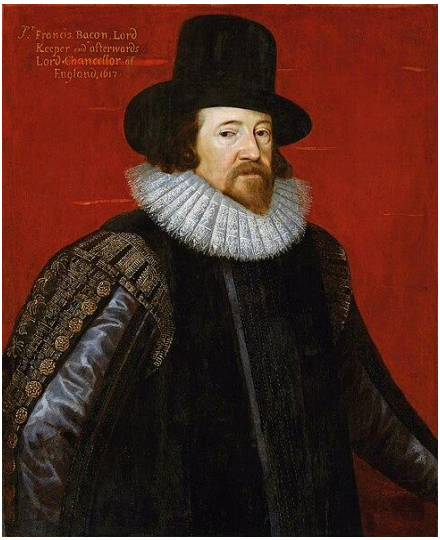


Figure 1-7. Portrait of Francis Bacon[20]

Although Bacon had a notable political career, he is best known for his book “Novum Organum”. The title, written in Latin, translates to “The New System”, “The New Way”, or even “The New Machine” in English. This title references Aristotle's[21] influential work, “Organon”. At Bacon's time, Aristotle's

[20] Painted in 1617 (91 x 74.5 cm^2), the artwork is titled Portrait of des Francis Bacon (Dutch: Porträt des Francis Bacon). It is housed in the Łazienki Palace in Poland and is catalogued under accession number ŁKr 896.

[21] Aristotle (Greek: Ἀριστοτέλης) (384–322 BCE) was a classical Greek philosopher and polymath.

approach to understanding the world was still dominant.

Although Aristotle was an reputed philosopher, his views on optics, biology, and women were notably invalid. The primary issue with Aristotle's approach was his lack of observation, experimentation, and critical thinking. Bacon argued that these elements were essential to the new scientific method. For example, according to Aristotle:[22]

"Women have fewer teeth than men"

This argument is invalid and can be easily disproven by simply examining and counting inside any woman's mouth. Like Al-Hasan, Bacon emphasised the importance of observation and reasoning, and he

[22] This quotation is taken from Bertrand Russell's work The Impact of Science on Society (see p. 6 in [BKE06]). Despite its broad dissemination following Russell's publication, several critics have challenged his interpretation of Aristotle's original text.

also maintained that the observer must remain impartial.

Bacon was convinced that errors in mental processing obstruct human progress. He used the "Idol"[23] to describe his idea, and identified four categories of these "Idols of the mind". They are:

1. Idols of the tribe
2. Idols of the cave
3. Idols of the market
4. Idols of the theatre

In the following sections, each of the Idols will be briefly described.

Idols of the tribe

For Bacon, the "tribe" represents all of humankind, meaning these idols are common to everyone.

Examples of idols in this category include the tendency to overgeneralise and make hasty

[23] An idol is a thing that is loved and admired very much.

conclusions, as well as the influence of emotions on judgement.

Idols of the cave

The second group of idols is named after Plato's Cave.[24]

Long before Bacon, Plato[25] used the cave as a metaphor to describe how an individual's perception of reality can be easily proven false or inaccurate. Figure 1-8 provides an illustration of Plato's cave.

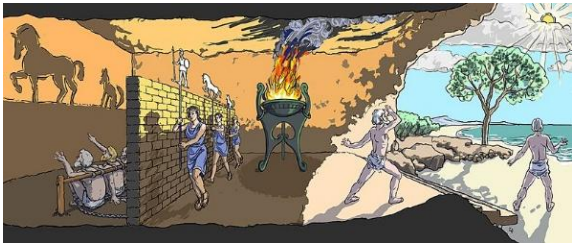


Figure 1-8. Plato's Cave[26]

[24] This allegory is discussed in Plato's work: "The Republic" (Greek: Πολιτεία), written around 375 BCE.

[25] Plato (Greek: Πλάτων) (42? – 348 BCE), an ancient Greece philosopher born and died in Athens. He is known for creating written dialogue and dialectic forms in philosophy, and for raising problems in major areas of both theoretical and practical philosophy.

[26] Image created by "4edges" published online on 24 October 2018. Licensed under CC BY SA 4.0.

Plato asked people to imagine a group of prisoners chained to a wall inside a cave, with their faces always turned toward the wall. Behind them, a great fire burns, and people move objects in front of it. The prisoners can only see the shadows of these objects, not the objects themselves.

This scenario serves as a metaphor for reality, represented by the objects, and our understanding of it, represented by the shadows.

Unfortunately, this is the only part of Plato's Cave that is relevant to understanding the idol of the cave. The remainder of the story takes a different direction, which is not aligned with the purpose of this section and will therefore be deliberately left out.

Since the prisoners in Plato's Cave have never seen a horse, for example, they will begin to judge what they see based on their feelings, creating a barrier that separates them from reality.

These idols represent all forms of human perspectives and ideas about physical world and society. Extreme versions of atheism, nationalism, or socialism fit into this category. These idols become mind-blocking when individuals stop perceiving the world objectively and view it only through their narrow perspective.

Idols of the market

For Bacon, the “market” symbolises society. This barrier arises directly from the interactions between people in public spaces. Bacon argued that this issue originates from the use of language, where words can sometimes be too simplistic and thus misleading. For instance, the word “Earth” can refer to either the planet or its surface. Similarly, the word “home” might signify the apartment where someone lives, the place where they were born, or simply where they feel they belong. Another example is the question “Where are you from?” the response could

vary greatly, referring to a street, neighbourhood, city, or even a country.

The concept, over which the “idol of the market” was defined, also applies when language is overly complex. Sometimes, philosophers or scientists use specialised terminology that is inaccessible to non-experts. As a result, knowledge is confined to a small group of people with the necessary expertise. This underscores the importance of science popularisation: to break down these barriers and make knowledge accessible to a broader audience.[27]

For instance, Figure 1-9 shows a polyhedron known as a Rhombicosidodecahedron. This is an abbreviated form of its full name: “Truncated icosidodecahedral rhombus, with icosidodecahedral rhombus”.

[27] This is one of the main reasons why footnotes are utilised in this book.

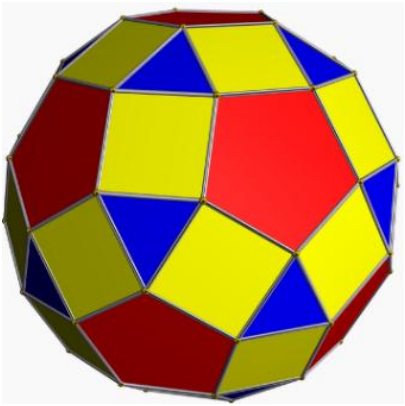


Figure 1-9. Rhombicosidodecahedron

The idols of the theatre

The final group of Idols are the Idols of the theatre. To Bacon, the theatre represents human heritage, and the actors within it symbolise influential figures from history. Bacon emphasised that people should not accept ideas simply because they were proposed by a renowned figure.

A classic example of the Idols of the theatre is the emission theory of vision. For centuries, it was widely believed that vision occurred because the human eye emitted radiation towards objects, a claim supported by some Greek philosophers, including Plato.

It may seem naive by today's standards, but this was a widely accepted belief for centuries! People simply trusted this claim because influential figures endorsed it, even though the claim could easily be disproven. After all, humans are unable to see in complete darkness.

René Descartes (1596-1650)

The final figure to discuss is René Descartes, born in the late 16th century. Descartes is well-known for his famous statement, which can be translated into English as:[28]

"I think, therefore I am"

[28] The original sentence first appeared in Discourse on the Method (French: Discours de la Méthode), specifically in the first paragraph of its fourth section. It is written in French as: je pense, donc je suis. See vol. 1, p. 158 in [BKF01].

Figure 10. Portrait of René Descartes[29]

Descartes rejected any idea that had not been tested. In his writings, he consistently emphasised doubt and critical thinking. He is also known for his book "Discourse on the Method".[30] in which he developed

[29] Painted around 1675 (77.5x68.5 cm²) by an unknown artist. This artwork is housed in the Louvre Museum in France, with the accession number INV 1317.

[30] The original title in French is "Discours de la Méthode Pour bien conduire sa raison, et chercher la vérité dans les sciences", which translates to "Discourse on the Method of Rightly Conducting One's Reason and of Seeking Truth in the Sciences". It was published in Leiden in 1637.

a systematic approach to research. He described his method as follows:[31]

The true method by which to arrive at the knowledge

Descartes's method is founded on four key principles: certitude, analysis, synthesis, and total induction. Here is a brief overview of each principle:

- **Certitude**: Also known as the rule of doubt, this principle dictates that nothing should be accepted without verification, regardless of its popularity or the respect it commands. Descartes advocated for a thorough questioning of all assumptions at least once.
- **Analysis**: This involves breaking down a problem into smaller, more manageable

[31] The original text reads in French: “et à chercher la vraie méthode pour parvenir à la connoissance”. See Vol. 1, p. 158 in [BKF01].

components and solving each one individually. The focus should be on defining and understanding the problem before attempting to solve it, rather than rushing to conclusions

- **Synthesis**: This principle involves using reason to integrate the solutions of the smaller problems to address the original issue. It is a process that researchers apply when writing theses or academic articles, where they build from verified, smaller scientific facts to broader generalisations.
- **Total Induction**: This principle stresses the importance of repeated testing and validation. As Al-Hasan suggested, researchers should thoroughly examine their own ideas to ensure they are robust, and that no critical aspect has been overlooked.

Scientific facts

Introduction

Knowledge refers to the awareness of facts, understanding of situations, and the practical skills that individuals possess. In addition to that, Chapter 1 highlighted that facts are a form of knowledge representing our best current understanding of reality. Since knowledge constantly evolves, facts also change as new technologies and discoveries emerge.

Facts can be scientifically established when obtained through a systematic and testable process. Such facts are considered scientific. However, not all facts are created this way. Many are based solely on personal perception, interpretation, or indoctrination.

Chapter 2 focuses on facts, especially scientific ones. Its aim is to clarify: what is a fact? How is it created? And how is it managed? The chapter also introduces

the concept of the research method, setting the stage for Chapter 3, which will focus on this topic.

This chapter is structured as follows: it begins by examining facts as pieces of knowledge. Next, the evolution of facts is explored from two distinct perspectives: simple and complex. While the human mind continuously generates simple facts, creating complex facts is a more challenging task. This process is neither quick nor straightforward; in fact, complex facts often take centuries to reach a stable form. The chapter concludes with general remarks on scientific facts, emphasising the difference between facts and scientific laws.

Facts as knowledge

Referring back to Chapter 1, it was established that facts are a specific type of knowledge. However, this relationship is not bidirectional. While facts are knowledge, not all knowledge qualifies as a fact. Knowledge encompasses much more, including aspects like emotions.

Facts are also connected to reality, but while reality is constant, facts can change. Reality exists as it is, independent of observation, and remains fixed. In contrast, human understanding of the world evolves as tools and technologies advance.

The “fact” in the common sense

In the following sections, the method for comprehending new, complex concepts will be applied, as outlined in detail in Chapter 1.

The process begins by understanding what a fact means in everyday language. According to the Oxford Learner's Dictionary, the definition of “fact” is as follows:

“A thing that is known to be true especially when it can be proved”

In Cambridge Dictionary it reads as follow:

"Something that is known to have happened or to exist especially something for which proof exists or about which there is information"

Finally in Merriam Webster Dictionary it reads:

"Something that has actual existence, or a piece of information presented as having objective reality"

To analyse this, similarities will be sought. Starting with the Oxford and Cambridge dictionaries, both share a similar idea. The term "known" appears in both definitions. In this context, the word "known" does not refer to personal knowledge or emotions, but to collective knowledge, where a consensus is reached among a group of people.

This accepted knowledge may also be false or invalid, but that is not the focus here. For example, when people believed the Earth was flat, this belief was considered a fact for centuries.

The second part of both definitions highlights a specific characteristic of facts: they are associated with proof. The first definition uses the term “proved”, while the second uses “proof.” Proof refers to physical evidence, consensus, or reasoning used to establish the validity of a statement. Therefore, facts hold greater value when they are supported by proof, however, this is not a requirement for establishing a fact.

To prove something, a method must be employed. If this method is systematic and testable, it aligns with scientific principles. Conversely, if the method is based on dogma[32], it often serves propaganda. It involves presenting information as fact to manipulate

[32] From Greek: δόγμαm via Latin. Literally, it means an opinion, belief, or judgment. In modern use, it means principle laid down as unquestioningly true in an ideology or belief system.

people and make them believe statements that are not valid.

The third definition includes the term “reality”, underscoring the requirement for knowledge to be presented as reflecting an objective reality in order to be considered a fact.

However, a fact is not necessarily the same as valid knowledge. According to the third definition, if someone presents their knowledge as an explanation of reality and manages to convince others of its validity, it is recognised as a fact. Thus, a fact does not need to be always valid; it may still be invalid! This is often referred to as propaganda.

Etymology of “fact”

The term “fact” can be traced back to Old English, where it has been used in its current form since the 16th century. The word's origins can be further traced to Latin through Old French.

In Roman times, the term “factum” referred to an event, occurrence, or achievement. Notably, the

significance of this term relies on a shared agreement among people about what constitutes an achievement. The emphasis is on collective agreement rather than the intrinsic validity of the achievement.

The word can also be traced back to a proto-indo-european suffix “dhe-”, pronounced like “the”, which meant to set or put.

Unfortunately, the meanings of words derived from this root have evolved significantly over time, making it difficult to see a direct connection with the modern use of the word “fact”. However, linguists agree that words like “do”, “affect”, and “affair” all share this common origin.

Returning to the historical usage of the word, its meaning has evolved significantly over the past four centuries:

- In the 16th century, “fact” referred to an action or something done, with clear agreement among people on its meaning.

- During the late 17th and 18th centuries, the term shifted to denote a truth established by observation or reliable testimony.
- By the 19th century, “fact” came to represent the fundamental reality of existence.

In summary, as human understanding of reality progresses, the term “fact” increasingly comes to represent reality itself.

Origin of facts

Based on the definitions reviewed, it is evident that facts arise from two main sources: consensus and reasoning.

Consensus refers to what a group of people agree upon. The critical aspect is not whether the fact is valid, but rather that there is agreement on it. The more widespread the agreement, the stronger and more accepted the fact becomes. Examples include human laws and conventions; these are considered facts because they are supported by people. When support fades, laws may be ignored or changed. For

instance, slavery was once universally accepted and legally authorised. Over time, as social and moral perspectives evolved, it was widely rejected, demonstrating that what was once considered a fact is no longer accepted today.

Languages and grammar serve as prime examples of facts based on consensus. People may use different names for things or express themselves in various ways. Grammar rules are also agreed upon collectively. As new generations emerge, they bring new vocabulary and expressions, which can lead to changes in the grammar of a language. Thus, languages and their grammar are considered facts, but these facts are only valid for those who use them. Over time, languages and grammar will continually evolve.

Conversely, reasoning involves using logic to generate new knowledge, with scientific facts resulting from this process.

Referring to the example of the Earth's shape (Figure 1-4): it is evident that the belief that “the Earth is flat” was established through consensus. In contrast, the scientific fact that “the Earth is spherical or nearly spherical” was derived through reasoning.

While reasoning challenges were thoroughly explored in Chapter 1, issues with consensus will now be examined to enhance the understanding of this process:

- People may agree on a invalid statement. Consensus does not guarantee accuracy. Instead, it only reflects how people are convinced.
- Appeal to popularity, it is a logical fallacy where people believe something is true merely because it has widespread support. Consensus can function in the same way, where individuals accept a “fact” not because it is verified or accurate, but simply due to others endorsing it.

- Consensus lacks a systematic approach and cannot be considered scientific. Conversely, consensus is often subjective and influenced by factors such as education levels and social contexts. Fear or manipulation can drive people to agree on irrational actions. As discussed in Chapter 1, science provides a structured way to generate verifiable knowledge.

What is a fact?

Building on the knowledge gathered, the next step is to tackle the question: What is a fact? However, the definition of a fact can vary depending on the field, whether in philosophy, law, history, or applied science. This chapter specifically focuses on scientific facts. Therefore, the question is refined to: What is a scientific fact? And The following is a proposed answer:

It is an objective and verifiable observation intended to explain or interpret natural or human-made phenomena

This definition incorporates the four key terms identified in the previous section: objective, verifiable, observation, and human-made phenomena. These terms contribute to the definition in the following way:

- **Objective**: The scientist must remain impartial, without personal bias, allowing the facts to guide their conclusions.
- **Verifiable**: This means the fact can be tested. Anyone equipped with the necessary tools and knowledge can verify its accuracy.
- **Observation** and **human-made phenomena** (i.e., experimentation) are two methods for generating knowledge, thoroughly covered in Chapter 1.

Classifications of facts

Facts can be classified based on both time and structure. The temporal view looks at how stable a fact remains over time, while the structural view examines the nature of the fact and how it is constructed.

Each of these perspectives will be discussed in the next section. Before proceeding, it is important to recall that facts can be illustrated using the five-axis RADAR diagram introduced in Chapter 1, However, for simplicity, the following section will concentrate only on the axes of credibility and complexity.

Time basis

In a time-based classification, the focus is on the relationship between credibility and time. Some facts are constant over time, meaning their validity does not depend on when they are observed.

Time-based classification doesn't imply that facts remain unchanged. facts do evolve. However, the

cause of this change is not the passage of time itself, but rather new discoveries or revised calculations.

For instance, the fact that “gold is a metal” remains true, as long as the definitions of gold and metals stay the same. Time does not affect this fact.

However, some facts are time-dependent, meaning their validity relies on time-sensitive variables. For example, the statement “Joe Biden” is the US president" is accurate at the time this book was published. But if you look 10 years into the past or future, this fact will no longer be valid, as it depends on the presidency term, which is time-bound.

Structural basis

Facts can also be categorised based on their structure, as either simple or complex.

- Simple facts are derived from basic knowledge that anyone can observe through their senses. For instance, “Summer is usually hot” is a simple fact. However, some might argue that this fact depends on other

underlying facts, as the concept of "summer" itself can be viewed as complex and open to further simplification. This process could continue indefinitely.[33] To define simple facts more precisely, a lower threshold of common understanding must be established, representing the basic collective knowledge shared within a group. While this threshold may vary between groups, it still exists, and all facts that fall within this common knowledge are considered simple.

- Complex facts represent sophisticated constructed knowledge. For instance, the fact that "the area of a circle is equal to πr^2" is considered a complex fact. While it may seem straightforward, it involves several advanced

[33] There is ongoing debate among semanticists about whether it is even possible to define concepts, particularly simple ones. For further discussion on this topic, refer to the introduction of [BKE07].

concepts that are not based on simple knowledge:

- A circle, a flat, round shape where every point on its edge is the same distance from a central point known as the centre
- An area, which refers to the size or measurement of the surface of an object.
- The radius, a straight line from the centre of the circle to any point on its edge.
- Pi[34], a complex mathematical concept. A constant approximately equal to 3.14. However, its precise value cannot be calculated exactly.
- Square function is also used. it involves multiplying a number by itself.

[34] Represented by the Greek letter π, Pi is a mathematical constant that denotes the ratio of a circle's circumference to its diameter. As an irrational number, Pi cannot be precisely expressed as a ratio of two integers. Consequently, no matter how many digits are used, Pi can never be exactly represented. However, with the help of calculus, Pi can be calculated to a high degree of precision, extending to hundreds of digits.

- Multiplication function, a mathematical operation used to find the product of a number by adding it to itself repeatedly.

Each of the concepts mentioned above can be broken down further into more basic ideas.

Facts development

Simple fact

As mentioned earlier, simple facts are typically part of a group's shared knowledge and are commonly used in everyday life. They do not require advanced skills to understand or apply.

Figure 2-1 illustrates the process of development of a simple fact starts from a physical phenomenon.

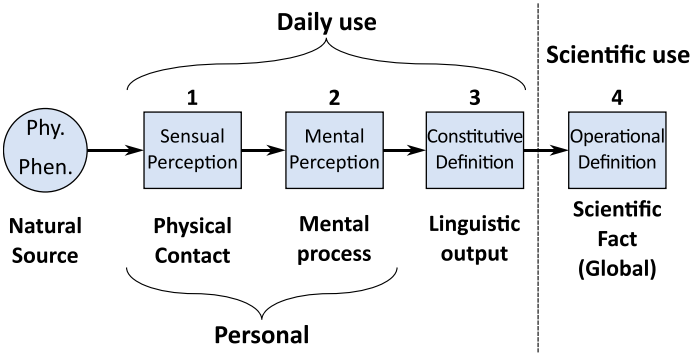


Figure 2-1. Development of a simple fact

The process of generating simple facts begins with natural sources. Humans rely on their senses to interpret the world around them. Sensual perception plays a crucial role as people observe phenomena, hear, touch, and physically interact with them.

The following step involves mentally processing the information gathered through the senses. This stage is entirely individual, as each person has unique experiences and skills, leading to variations in how the data is processed and, consequently, in the resulting conclusions.

It is essential to recognise that the first two steps are entirely personal, meaning each individual can carry them out independently. In contrast, the third step is a collective process. This is known as the constitutive definition, where a phenomenon is given a name that is accepted and used by a group of people.

Different groups may use various terms to describe the same concept, and they might not capture all its aspects. For instance, they might only highlight one

or two features, which is perfectly fine as long as the fact serves the group's practical needs in daily life. This is the primary purpose of simple facts.

Simple facts can also be applied in science, but they must undergo an additional step involving the scientific method.[35] The simple fact is tested multiple times and may be combined with others to cover all aspects of the phenomenon. This process is known as creating an operational definition.

While constitutive definitions are specific to local groups and their contexts, operational definitions are broader and aim to encompass as many aspects of the phenomenon as possible. At this stage, the fact is ready for scientific application.

Figure 2-2 shows the fire as an example. It is a physical phenomenon, and individuals may have varied experiences with it:

[35] Chapter 4 is dedicated to the scientific method.

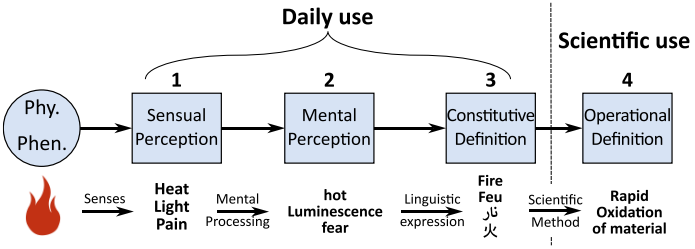


Figure 2-2. Development of a simple fact: fire example

- Some individuals may use it as a source of heat.
- Others may use it to provide light.
- Others may have been burned by it, and thus, associate fire with painful memories.

It is evident that heat, light, and pain are directly linked to sensory experiences. The brain then processes these sensory inputs. In the example given, the physical phenomenon transforms into abstract mental perceptions: for instance, heat is perceived as hot, while pain may evoke feelings of fear, and so on. Thus, varying experiences lead to different interpretations. For example, a fire that destroys a home will be perceived very differently by those

affected compared to individuals who use fire for cooking in their daily lives. Consequently, the linguistic expressions used to describe these experiences will differ. People may use different terms to describe aspects of the phenomenon, which means that constitutive definitions may lack clarity and accuracy.

Finally, through scientific methods, a universally accepted definition of fire can be established. Fire is defined as the rapid oxidation of material.

Complex Fact

The creation of complex facts is not a straightforward everyday process. It relies heavily on reasoning and is grounded in logical analysis. Developing these complex facts requires advanced skills, making it the responsibility of scientists and philosophers.

Figure 2-3 shows the development of a complex fact. Similar to simple facts, the process begins with a physical phenomenon, which serves as the initial source for complex facts. Using sensors or

instruments, humans can observe and measure various aspects of the phenomenon. The gathered results are then analysed to generate a list of potential explanations.

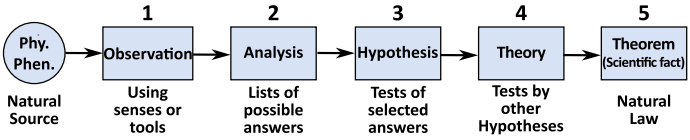


Figure 2-3. Development of a complex fact

Although each answer represents a potential explanation for the phenomenon, all must undergo verification. However, it is usually impractical to verify every item on the list. Therefore, through logical reasoning, only a few potential answers are chosen for deeper investigation.

This step can be challenging because the correct explanation might be overlooked. That is why individuals with advanced skills in logic and reasoning are essential, as they significantly reduce the likelihood of missing the accurate explanation.

However, it is always possible to miss the valid answer. If none of the selected answers succeeds in

the next steps, it may indicate that all are invalid, and the valid answer has not yet been proposed. This would require further observation or a more detailed analysis of the obtained results.

Each potential explanation is referred to as a hypothesis: a statement that must be tested. The next step involves evaluating the hypothesis by comparing it against known facts or laws to determine if the explanation aligns with them. If a hypothesis withstands several fact-checks, it gains scientific credibility. Strong hypotheses, when supported, can contribute to the formation of a theory.

A theory is a temporal explanation for a group of phenomena. Theories are not the final form and remain subject to testing. They can offer a reliable explanation for certain aspects of a phenomenon, but not necessarily for all of its components. A theory requires ongoing testing. Interestingly, this is done using less reliable hypotheses. A theory gains

strength when it can be validated by these hypotheses, and the more tests it successfully passes, the more it becomes accepted by scientists as a valid explanation for the phenomenon under investigation.

Finally, when there is no possible way to prove that a theory is invalid, and when the theory is capable of predicting the exact explanation and behaviour of the phenomenon, it becomes a theorem. A theorem is the natural law and the explanation of a natural or human-made phenomenon.

Here are a few examples to apply these abstract concepts to the physical world. The first example[36] is the Pythagorean theorem[37] (Figure 2-4).

[36] The following story is purely fictional, with no historical evidence to back it up.

[37] The Pythagorean theorem, named after the ancient Greek philosopher Pythagoras (circa 570 – 495 BCE), is a principle in Euclidean geometry that relates to the three sides of a right-angled triangle. It states that the area of the square built on the hypotenuse (the side opposite the right angle) is equal to the combined areas of the squares constructed on the other two sides.

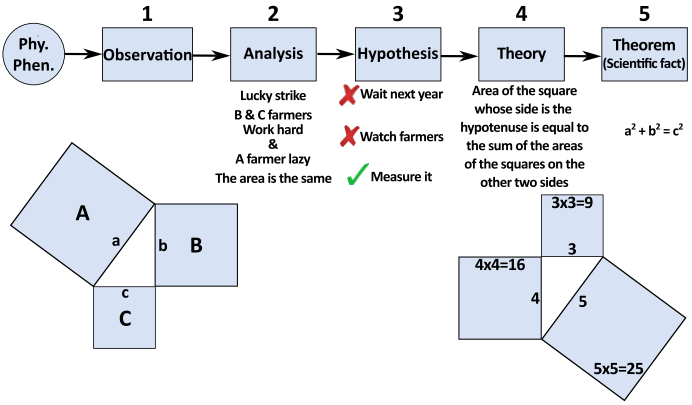


Figure 2-4. Development of a complex fact: Pythagorean theorem

Once upon a time, in a kingdom from the ancient world, farmers worked on the king's land and had to report their harvest to the King's officials. Farms A, B, and C were situated close to each other, as shown in Figure 2-4. It was obvious that Farm A was bigger than Farms B and C. The King's officials began to observe that the combined harvest of Farms B and C was almost equal to that of Farm A, which was an interesting observation.

The next step is to analyse the collected data, which in this case involves the observation. Here is a list of possible explanations for the observed phenomenon:

- It could be a coincidence.
- The farmers of Farms B and C might work harder, while the farmer of Farm A could be working less.
- The combined area of Farms B and C might be equal to the area of Farm A.

The King's men treated each possible explanation as a hypothesis and proceeded to test them:

- For the first hypothesis, they waited for the next year's harvest, and the result was the close to the first year. Even after the third year, there was no significant change, so this hypothesis was proven false.
- For the second hypothesis, the King's men observed the farmers and found that they were working at a similar pace. Therefore, this hypothesis was also invalid.
- For the third hypothesis, they measured the areas of the farms and found that the combined area of Farms B and C was indeed

equal to that of Farm A, confirming this hypothesis as true.

This outcome was sufficient for the King's men. However, a wise man in the king's court decided to explore further and wrote the following analysis:

"The area of the square whose side is the hypotonus is equal to the sum of the areas of the squares on the other two sides"

This is a theory. It is broad and abstract because it does not focus on particular farms. Instead, it can be applied universally when the conditions are met. In contrast, a hypothesis is tied to a specific, physical example.

As the story goes on, the King's men continued to measure the land in similar cases over the years. In every instance, the theory held true. Although it

cannot be definitively proven, its consistency led to it becoming the well-known Pythagorean theorem:[38]

$$a^2 = b^2 + c^2$$

Here is another example: gravity. A simple hypothesis about gravity would be that:

---

if an object is thrown or released in Earth's atmosphere, it will fall downward

---

This hypothesis is closely linked to the physical world, and it can be easily tested and observed.

In contrast, a theory explaining gravity would state the following:

It is a force attracting and uneven distribution of masses together

---

The theory is abstract. If the linking words are removed, it consists of just seven words, five of which are key "concepts" that require clear definitions to

[38] This equation can be read as follows: the area of a square is the value of its side squared.

fully understand the theory. These five concepts are “force”, “attraction”, “uneven”, “distribution”, and “mass”. For someone without a solid background in physics, it could take around 30 minutes to research and understand the meaning of each term before linking them together to make the theory clear.

The third example is dark matter. Scientists propose that it exists within the universe, though the mechanisms behind its presence remain undetermined. Apart from its existence, there is minimal empirical data available about dark matter. Consequently, there are no definitive explanations for its nature or behaviour at this time.

This section will conclude with definitions of “hypothesis”, “theory,” and “theorem” as provided by the Oxford Dictionary of Science. Here is the definition of “hypothesis”:[39]

[39] See the origins in the corresponding material in [BKE08].

"A hypothesis is a law that might not be universally true"

And on the theory:

"A theory is a description of nature that encompasses more than one law but has not achieved the incontrovertible status of a theorem"

And on the theorem:

"A theorem is a descriptive principle of nature that holds in all circumstances covered there are no loopholes in laws of nature and any exceptional event that did not comply with the law would require the existing theorem to be discarded"

The relationship between theories and hypothesis

In the previous section, it was demonstrated that while a hypothesis is closely related to the physical world, a theory is more abstract and logical in nature. However, the interplay between theories and hypotheses is much more complex.

As noted earlier, a hypothesis fulfils two key roles (Figure 2-5):

1. It is the basis of a new developed theory.
2. It is used to test other theories.

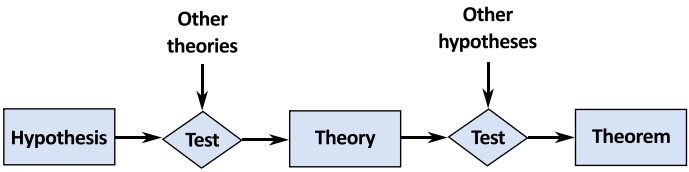


Figure 2-5. Relationship between theories and hypothesis

On the other hand, theories are used to test hypotheses. A hypothesis does not become a theory unless it has been thoroughly tested multiple times using various theories.

However, Figure 2-5 might misleadingly suggest that this process is linear and straightforward. In reality, it is not a quick or simple series of steps. Numerous challenges can arise, such as the lack of appropriate tools or insufficient technological advancements.

For instance, in 1905, Einstein's[40] suggested that gravity, if strong enough, can distort the time flow.[41] While this was well-defined in mathematical terms, the challenge was to find a method to test this concept. It took scientists over a century to develop the necessary technology to detect such distortions.[42]

The challenge may also arise from insufficient data, which necessitates additional testing to develop robust hypotheses. Even when all conditions are

[40] Albert Einstein (1879–1955), a theoretical physicist renowned for his development of the theory of relativity. He was awarded the Nobel Prize in Physics in 1921 "for his contributions to theoretical physics, and particularly for his discovery of the law of the photoelectric effect".

[41] See the original work, written in German, in [ARG01]. An English translation is available in [BKE09].

[42] See [ARE01] for more details.

fulfilled, exceptional intellect is still required to advance the process.

Essentially, the process involves a series of theories developed over varying periods, each contributing incrementally to human understanding. Ultimately, this leads to the formulation of a theorem.

The classical (Newtonian) and quantum mechanics are an example of this long chain of theories.

When Isaac Newton[43] developed a new framework for understanding mechanics, the equations he wrote was able to describe motion everywhere, from a wagon down the road to the stars in the far galaxies. Newtonian mechanics was considered universal, and at that time, there was no known phenomenon that seemed to contradict it. It was believed that Newton's laws applied universally throughout the cosmos.

[43] Sir Isaac Newton (1642–1727) was an English mathematician and physicist, and a fellow of the Royal Society. He is renowned for his development of Newtonian mechanics, his explanation of universal gravitation, his contributions to calculus and algebra, and his generalisation of the binomial theorem.

As technology advanced, scientists discovered extremely small entities such as atoms, neutrons, and electrons. The movement of electrons could not be explained by Newton's laws, revealing that these laws were not universally applicable as previously thought. This led to the development of a new branch of mechanics, known as quantum mechanics, to address the behaviour of these small entities. At the time of this book's publication, both Newtonian mechanics and quantum mechanics remain valid within their respective domains, and there is no "Theory of Everything"[44] that unifies the two.

Notes on scientific facts

On the credibility

Scientific facts are distinguished by the extent to which they have been tested (Figure 2-6).

[44] Also referred to as the final theory, ultimate theory, unified field theory, or master theory, it is a proposed, comprehensive theoretical framework in physics that aims to explain all aspects of the universe.

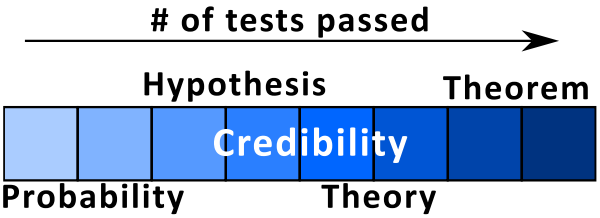


Figure 2-6. Tests and credibility of the scientific facts

At the lowest level of validation is probability, which represents a potential answer or explanation that has not yet been tested. The next level is the hypothesis, an explanation chosen for testing from a set of potential answers based on logical reasoning. Theories represent a more developed stage; they are provisional explanations of physical phenomena that typically integrate multiple hypotheses. A theory has undergone extensive testing and examination under various conditions but may not account for all aspects of the phenomenon and requires further refinement. The highest level of validation is the theorem, a well-established natural law that has no known exceptions. Once a theorem is formulated, it is considered valid.

On the process development

Developing complex facts involves a lengthy process. As previously discussed, this development is not linear but rather consists of a sequence of theories evolving over irregular time intervals.

Additionally, it is important to note that the process is not always unidirectional. While this chapter has presented it as progressing from specific facts to general ones, development can also move in the opposite direction.

In certain fields, such as the humanities, where human subjects are studied, the process often works from general principles to specific instances. For example, a judge in a court of law applies general laws to make specific rulings. In many cases, no specific law directly addresses the case at hand, so the judge must apply general principles deductively to form a particular judgment.

In most applied sciences, the process typically follows a inductive approach, moving from simple facts to the

formulation of theorems, with hypotheses and theories in between. This is true because applied sciences are based on physical nature, and their main objective is to explain it.

The concepts of “inductive” and “deductive” reasoning are key in this context (Figure 2-7). Deductive reasoning is used to build complex facts from basic principles. In contrast, inductive reasoning is employed to derive simple facts from complex observations.

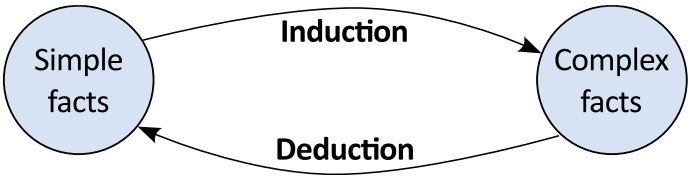


Figure 2-7. Relationship of simple and complex facts

Hypothesis Vs. assumption

There is a significant difference between an assumption and a hypothesis, though they are often incorrectly used as synonyms.

A hypothesis, as previously described, is a proposed explanation for a physical phenomenon that has yet to be tested for validity. Conversely, an assumption is a statement accepted as valid without evidence. For example, judging people based on their appearance is an assumption. Similarly, believing one can understand how others feel or think without direct communication is also an assumption.

On the truthiness and falsehood

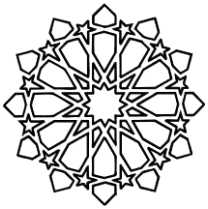
Scientific facts are not concerned with notions of truthiness or falsehood. In scientific discourse, terms like “right" or “wrong” are not appropriate. Instead, the terms “valid" and “invalid” are used, as seen throughout the first two chapters.

Scientific facts are inherently provisional, reflecting the ever-evolving nature of science. What is crucial from a scientific standpoint is that facts are testable and subject to validation. New discoveries or calculations may challenge existing scientific facts, and this is considered a constructive part of the

scientific process. Such challenges are integral to the advancement of science and are not viewed as confrontational or inappropriate.

Although science is continually evolving, this progression is not arbitrary. The scientific facts are subject to change does not imply that every valid fact today will necessarily become invalid in the future.

Science is directed by empirical evidence, and changes in scientific understanding generally lead to more precise and accurate models or laws. This process is irreversible, making it uncommon to disprove a theorem once it has been established. While it is not impossible for a theorem to be proven invalid, it is rare. The process of validating a theorem involves extensive testing, so it is unlikely for a theorem to be invalidated. Later, however, it is possible for a theorem to be refined or expanded to account for new information.



Research methodology

Introduction

In the previous two chapters, both knowledge and scientific facts were explored in detail. Chapter 1 focused on knowledge, demonstrating that facts are a specific form of knowledge. Chapter 2 expanded on the concept of facts, distinguishing between simple and complex facts. The chapter concluded that Scientific facts, as complex facts, are developed through scientific methods.

This chapter will focus on research methodology, aiming to clarify the various types of research methods and the different approaches that can be applied within them. This will pave the way for Chapter 4, where the scientific method will be examined in detail.

Chapter 3 is divided into four main topics: First, defining what a research method is, followed by an explanation of methodology and the importance of

distinguishing between the two. Third, research methods will be classified into three types: descriptive, deductive, and inductive, with examples provided for each. Finally, different approach will be discussed, including literary, promotive, and scientific with a special focus on how the scientific approach differs from others.

Getting started: methods defined so far

Figure 3-1 illustrates the creation of both simple and complex facts as discussed in Chapter 2. It outlines a specific method for generating simple facts, consisting of four sequential steps to be followed in order to achieve the desired result. A similar approach applies to complex facts, shown below in the figure, each box has his own number and label that describes it.

In both cases, the sequence of steps is crucial, which is why each step is numbered. The steps must be carried out in the correct order, as it is not possible to

complete Step 3 before Step 2. The output of each step serves as the input for the next. This structured process, is referred to as a method.

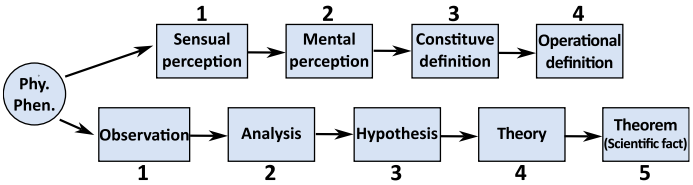


Figure 3-1. Schematic diagram from creating simple and complex facts

Another approach was used to determine the meaning of a complex concept in the first two chapters (Figure 3-2). The process involves the following steps:

1. Searching for the definition of the word that describes the concept in general-purpose dictionaries, such as the Oxford Learner's Dictionaries, Cambridge Dictionary, and Merriam-Webster Dictionary.
2. Investigating the etymology of the word to understand its origins.
3. Looking for the word's meaning within a specific-field or domain.

4. Using the knowledge gathered from the first three steps to formulate a precise definition of the word.

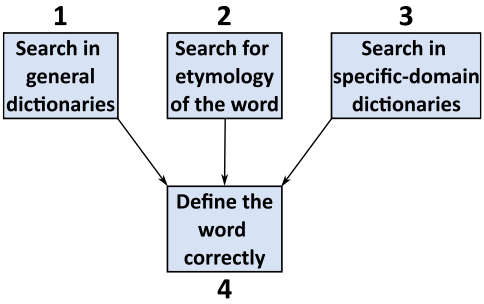


Figure 3-2. Method for defining a new concept.

Although these steps are numbered, their execution does not have to follow a strict sequence. The process can begin at any step, whether it is Step 1, Step 2, or Step 3. The order of execution can vary, such as Step 1 followed by Step 2 and Step 3, or even Step 3 followed by Step 2 and then Step 1. As long as all three steps are completed before moving on to Step 4, the outcome will be the same. The key is to ensure the steps are defined in detail.

In simple terms, a research method is a structured approach to generating new knowledge, where a

specific set of rules or steps is followed. These steps can be either ordered or flexible. If the knowledge gained is a scientific fact, the process is known as a scientific method.

Method vs. methodology

The terms “method” and “methodology” are often used interchangeably, but they represent distinct concepts. To understand the difference, it is important to define each term.

The steps outlined earlier in the chapter will be applied to define both “method” and “methodology”, as a new concepts, enabling a comparison between the two.

Method

The starting point is the common dictionaries. In Oxford Learner’s Dictionaries, the entry reads:

“A particular way of doing something”

The definition is identical, word for word, in the Cambridge Dictionary.

In the Merriam-Webster Dictionary, the entry for "method" reads:

"A way, technique or a process of or for doing something"

All three dictionaries agree that a "method" is defined as "a way of doing something". Merriam-Webster further elaborates by stating that it may also refer to "a technique or a process".

Tracing the etymology of the word, it originates from Latin, where it meant "an inquiry or investigation", and its roots can be traced further back to Ancient Greek, where "methodos"[45] signified "a pursuit or following after". By the early 15th century, "method" was used to describe "a regular or systematic

[45] Romanised form Greek: μέθοδος.

treatment of a disease". By the late 17th century, the meaning of the word had evolved significantly to refer to "a system or set of rules designed to achieve a specific goal", a definition that remains in use today.

The first part of the word is "meta", which is a complex prefix with multiple meanings. Misinterpreting or confusing these meanings can result in an idol of the market, thoroughly discussed in Chapter 1 of the book.

The suffix meta has the following meanings:

- After, in a physical sense, such as one object positioned behind another.
- Beyond, in a non-physical sense, referring to ideas that go beyond a particular concept.[46]

[46] As discussed in Chapter 1, idols of the market are obstacles to logical thinking, often arising from language misuse. The term "metaphysics" emerged from a misunderstanding of two meanings of "meta". Originally, Aristotle's 12th work was on physics, and the term "metaphysics" referred to the 13th work, which literally meant "after physics" on the shelf. However, the=

- To change, as seen in words like “metabolism”.
- Across or over, which is the relevant meaning in the word “method”. Other English words, like “metaphor”, use this same meaning for the prefix.

The second part of the word is “hodos”,[47] which also has multiple meanings, but the most relevant for this context is “way” or “road”. The “hodos” element appears in many modern English words. For instance, “Exodus”,[48] from Judeo-Christian tradition, literally means “the way out”.

Another example is the word “episode”, which is commonly used in modern media to refer to a part of

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= 13th work dealt with the study of the fundamental nature of reality, involving spiritual aspects. Over time, “meta” was misinterpreted to mean “beyond”, and “physics” was understood as referring to material things. As a result, metaphysics came to represent the study of what lies beyond the physical world, rather than its original meaning.

[47] Romanised from the Greek: ὁδός.

[48] Romanised from the Greek “ἔξοδος”, it is now known as the Book of Exodus. This is the second book in both the Jewish Torah and the Christian Bible.

a series. However, its original meaning was different, referring to “something added along the way”.

Finally, the word "diode" serves as a third example. It is the name of a semiconductor device and is composed of two parts:

- “di-”, meaning two.
- “hodos”, meaning road.

Together, the two parts denote a device with two terminals.

Combining the meanings of “meta” and “hodos”, the Greek term translates to “a following after”.

Methodology

Starting with the general meaning of the word “methodology”, the common dictionaries will be consulted. According to the Oxford Learner's Dictionaries, the entry for “methodology” reads as follows:

"A set of methods and principles used to perform a particular activity"

In Cambridge dictionary, the entry reads as follow:

"A system of ways of doing teaching or studying something"

The term "way" is synonymous with "method", as previously noted. Therefore, it is reasonable to interpret the definition from the Cambridge Dictionary as:

"System of methods"

Finally, in Merriam-Webster dictionary, the entry reads:

"A body of methods, rules, and postulates employed by a discipline"

Examining the three definitions, the terms "set", "system", and "body" all indicate a group, in this case, a collection of methods that share a common purpose: they can be applied to a particular activity or used to study a specific subject. Therefore, while a method is a sequence of steps followed to systematically address a task, a methodology refers to a set of methods employed within a specific field.

Etymologically, the word "methodology" has been in use since the 19th century, initially meaning "a branch of logic concerned with how abstract logical principles are applied to the generation of knowledge".

The word "methodology" can be traced back to Latin via French. In all instances, it is evident that the word consists of two components: "method" and the suffix

“-logy”. The first part, “method” has already been examined in the previous section.

On the other hand, the suffix “-logy” is added to the end of a word to give it a specific meaning: a branch of knowledge or science. It appears in commonly used terms like “biology” meaning the study of living organisms. Another example is “geology”, where the prefix[49] “geo-” refers to Earth, making geology the science of Earth's physical structure. Lastly, “egyptology" refers to the study of ancient Egypt.

Following the same reasoning, “methodology” can be defined as: the science that studies the methods applied within a specific field.

Difference In the research domain

In this book, the emphasis is not on the broad, general meaning of the word “method”, but rather on its specific application in research. Therefore, the question can be reframed as: What precisely is a

[49] A prefix is a group of letters attached to the beginning of a word to give it a specific meaning.

research method? The following provides a clear answer:[50]

> *"Research methods are the strategies processes or techniques utilised in the collection of data or evidence for analysis in order to uncover new information or create better understanding of a topic"*

A closer examination of this definition reveals that a research method is a tool or process employed to systematically generate new knowledge.

In contrast, the definition of methodology is provided in The Cambridge Dictionary of Philosophy as follows:[51]

[50] This definition is quoted form the research guide of University of Newcastle, see the original text in [WEB01].
[51] See p. 820 in [BKE10].

"The branch of philosophy of science that explores the methods by which signs arrive at its truth and critically explores rationales for these methods"

Thus, in research domain, methodology refers to the systematic study of research methods.

What stands out in this definition is the term "critically". When the structure of research methods is examined later in Chapter 4, attention will be given to the potential risks of corruption or misuse, which can lead to invalid results. This is where methodology plays a crucial role, by critically, assessing and refining research methods to ensure accuracy and validity.

Classification of research method

Classification is the process of grouping things based on shared qualities or characteristics. It involves assigning an adjective to objects that are being described.

In this section, research methods will be classified based on how they produce knowledge. The three primary classes are descriptive, deductive, and inductive methods. Each will be explored in detail with several examples.

Descriptive methods

The primary goal of the descriptive method is to provide detailed scientific accounts of various objects. In this context, an "object" refers to anything that has an impact, whether physical or conceptual. For instance, taxonomy focuses on classifying organisms, which are physical entities that can be observed, measured, or sometimes heard. On the other hand, the subject of study might be non-physical, like human behaviour. Anthropology,[52] for example, examines humankind, exploring aspects such as culture, folklore, and traditions.

[52] Anthropo- is a prefix means pertaining to man or human beings, it is derived from Greek word ἄνθρωπος (Romanised: anthrōpos) which means human.

Anthropologists describe intangible elements of human societies, such as political systems, wedding songs, and religious practices.

The term “scientifically” in this context indicates that the description must follow a structured approach, rather than being arbitrary, and should involve analysis of the collected data. Therefore, a descriptive method must possess the following three characteristics:

1. The descriptive method must be objective and encompass all aspects of the phenomenon being studied. The observer should avoid including personal opinions or interpretations in the recorded descriptions. This does not mean that opinions cannot be expressed, but personal reflections, thoughts, and opinions should be entirely separate from the collected data.
2. The data gathered should be organised into predetermined classes. For instance,

information about structure or layout should be grouped together, as should data describing behaviour. These classes must be defined prior to the description process so the researcher knows exactly what to focus on.

3. Within each class, the data should be sorted in a specific, systematic order that suits the type of information. This could be in ascending or descending order, chronologically, or according to another predefined system.

It is essential to recognise the difference between classification and sorting. Classification involves grouping the collected data based on their type, such as time-related data, length-related data, etc. This process handles heterogeneous[53] data, meaning data processed vary in nature or content.

[53] Hetero- is a prefix that means other or different. It is derived from Greek word ἕτερος (Romanised: héteros) which has the same meaning.

In contrast, sorting involves arranging the data within each group in a specific order. Sorting deals with homogeneous[54] data, meaning processed data are similar in kind or nature.

A descriptive method may incorporate inductive steps to generate new knowledge from the collected data; however, the primary process remains descriptive.

The descriptive methods can be also subclassified into two main subclasses, documentary and contemporary.

A documentary descriptive method emphasises the examination of objects from the past and is primarily utilised in historical and religious studies. In contrast, contemporary methods concentrate on current objects. Notable fields where this research approach dominates include cartography, the practice of map-

[54] Homo- is a prefix that means same, like or equal. It is derived from Greek word ὁμο (Romanised: homo) which has the same meaning.

making, and astronomy, which studies outer space and the physical universe.

In certain fields of knowledge, both documentary and contemporary research methods are extensively employed. Taxonomy serves as an example of such a field. It is a branch of biology that is not only focusing on the classification of extinct organisms based on their fossils but also extend to studying living species. The following section will discuss three examples of descriptive methods.

Example 1: Hadith studies

The first example to study is closely related to religion, specifically Islam, and is centred on Hadith[55] studies. In this context, a hadith refers to the recorded words, actions, and silent approvals of the Prophet Muhammad[56], conveyed through a chain of narrators.

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[55] From Arabic: حديث (Ḥadīth), literally, it means a conversation or a talk.

[56] Muhammad ibn Abdullah (Arabic: مُحَمَّد بن عبد الله) (570 - 632 CE), an Arab religious, social, and political leader and the founder of Islam.

The analysis of a specific hadith focuses on its reliability, particularly its level of authenticity. Notably, Muslim scholars developed a systematic and strict system for categorising hadiths. This research method is one of the oldest still in practice today.

Hadith studies method consists of several specific steps to ensure the reliability of the hadith. First, scholars examine the chain of narrators, to verify each person's credibility. This includes looking into their biographies, checking if they were known for honesty and good character, and assessing their memory and accuracy in narration. Next, text of the hadith, is examined carefully for consistency with established Islamic teachings and other authentic sources. Scholars also evaluate the content for any historical context or linguistic characteristics that may affect its interpretation.

In addition to these primary checks, scholars classify hadith into different categories based on their authenticity: authentic, good, weak, and fabricated.

They also consider the context in which the hadith was reported, including the circumstances surrounding its transmission and any potential biases of the narrators.

Some may contend that religious studies rely on a set of postulates[57] or assumptions[58], which renders them invalid. However, this argument itself is invalid.

Religious studies are not unique in incorporating postulates. For instance, geometry is founded on a specific set of postulates and operates effectively, at least from a methodological perspective.

One of the most well-known postulates of all time is the following (Figure 3-3):

if a line C intersect with two lines called A and B, and if the angles a and b are equal, then, the lines A and B are parallel

[57] It means an argument that is taken for granted without proof.
[58] As discussed in Chapter 1, an assumption is a statement that is believed to be true or accepted as it is with no proof.

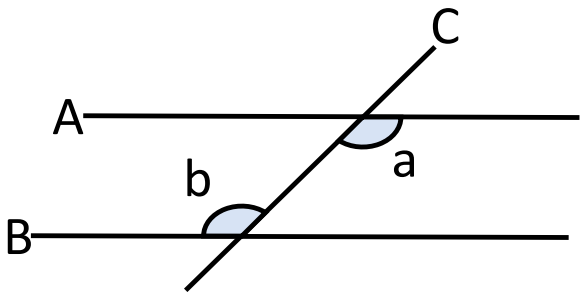

Figure 3-3. The fifth postulate of Euclid.

This is Euclid's[59] 5th postulate, which was not confirmed as valid until the mid-19th century. Nevertheless, Euclidean geometry, based on this postulate, developed without any issues.

Therefore, having postulates does not invalidate a method. However, when postulates are established, a set of rules must be followed to avoid developing an invalid method:

- The postulates should be clear from the outset. Introducing postulates during the course of research is a warning sign for

[59] Euclid (Greek: Εὐκλείδης) (?? - 300 BCE) an ancient Greek mathematician, best known for creating a branch of geometry named after him: the Euclidean geometry.

corruption and can lead to a compromised research method.

- Postulates are intended to facilitate the generation of new knowledge, not to create it.
- Postulates must not be used to manipulate results or to steer them in a specific direction.

Example 2: Historical method

The historical method is employed by historians to assess historicity of objects and events. This method does not rely on postulates or preconceived assumptions; its main objective is to uncover the original form and narrative of past events.

Thanks to this approach, history is not merely a collection of stories; each documented event can be validated based on its context and the archaeological record.

The historical method involves three steps to verify the existence of the subject under investigation:

1. Physical remains of the subject are examined. If remains are found, they are considered definitive evidence of the subject's existence.
2. Artefacts used or created by the subject are identified, such as swords, shields, letters, or possibly tombs and statues. It is essential that these objects are traceable directly to the subject. If such artefacts are discovered, they are regarded as strong evidence of the subject's existence.
3. Contemporary sources are reviewed, dated to the period when the subject is believed to have existed, or as close to that period as possible. If the subject is mentioned in these sources, particularly in independent ones to avoid conflicts of interest,[60] this is seen as a reliable indication of the subject's existence.

[60] A situation arises when there are concerns that someone is involved in multiple activities, one of which might corrupt the motivation of another activity.

Here is an example to illustrate how the historical method operates: how can it be determined whether Alexander the Great[61] and Bilbo Baggins[62] actually existed?

By applying the three steps of the historical method to both figures:

- **Physical remains**: Neither Alexander the Great nor Bilbo Baggins has any known physical remains.
- **Artefacts**: There are no surviving objects directly associated with either figure. However, coins minted during Alexander the Great's reign have been found (Figure 3-4). The earliest known depiction of him dates

[61] Also known as Alexander III of Macedon (Greek: Ἀλέξανδρος, Romanised: Alexandros) (356 - 323 BCE), the king of Macedonia and the conqueror of Achaemenid Persia. He is most famous for his military campaigns in Asia, which played a significant role in bridging the Eastern and Western worlds.

[62] A fictional character from J.R.R. Tolkien's legendarium, Bilbo Baggins first appeared in the 1937 novel The Hobbit and later in The Lord of the Rings. He is best known for his bravery and love of adventure.

back to around 120 -100 BCE,[63] approximately two centuries after his death. For Bilbo Baggins, no tangible objects have ever been identified.

- **Contemporary sources**: Alexander the Great's military campaigns are well-documented by historians, with records dating to his lifetime or shortly thereafter.[64] In contrast, Bilbo Baggins is only mentioned in two fictional works, The Hobbit and The Lord of the Rings.

  Therefore, applying the historical method, it is reasonable to conclude that Bilbo Baggins

[63] The artwork is titled the "Alexander Mosaic", also known as the "Battle of Issus Mosaic". It is a Roman mosaic measuring 2.72 x 5.13 metres, discovered on the floor of the House of the Faun in Pompeii. The mosaic depicts the Battle of Issus and is currently part of the collection at the National Archaeological Museum in Naples. Accession number: Inv. 10020.

[64] Alexander the Great had even a historian following his campaign in real time. His name is Callisthenes of Olynthus (Greek: Καλλισθένης) (360 - 327 BCE).

did not exist, whereas Alexander the Great is recognised as a historical figure.

Figure 3-4. A coin dated back to the era of Alexander the Great[65]

Example 3: Taxonomy

The primary goal of taxonomy is to classify life forms based on their functions and physical characteristics. Taxonomists must describe organisms using a complex classification system.

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[65] The name "Alexander" (Greek: ΑΛΕΞΑΝΔΡΟΥ) can be seen on the reverse of the coin, which was likely struck between 333 and 327 BCE during Alexander the Great's lifetime. The letter "B" beneath the throne refers to Balakros (Greek: Βάλακρος), one of Alexander's bodyguards (Greek: Σωματοφύλακες, Romanised: somatophylax). The depictions on the coin are often mistakenly attributed to Alexander himself. However, the obverse features Heracles, the legendary ancestor of the Macedonian royal family, while the reverse depicts Zeus Aëtophoros seated on a throne. The image is from the Classical Numismatic Group (CNG). Coin Accession number: 368240, see [WEB02].

This process can be challenging and often influenced by misconceptions, such as the “Idols of the Market” discussed in Chapter 1. For example, if a bird is defined as “a flying animal”, this would include all insects. Adding the term “vertebrate” to exclude insects, defining a bird as “a vertebrate flying animal”, is still inaccurate, as bats are vertebrate flying animals but are mammals, not birds. Similarly, whales might be mistaken for fish, and fungi could be wrongly classified as plants.

To resolve these issues, clear and precise definitions are necessary to distinguish between what is classified as a fish, plant, or other organisms.

Therefore, the work of a taxonomist goes beyond merely collecting data and making observations. The information must be carefully classified and organised to transform it into useful knowledge, and this is a key part of the descriptive method employed in taxonomy.

Deductive methods

The second category of research methods is the deductive method. Deduction refers to moving from the general to the specific. Therefore, a deductive research method involves answering a question or solving a problem by starting with general principles or facts and narrowing down to specific conclusions.

Example: Court judges

A domain where the deductive research method is applied is in modern courts. A judge's work, for instance, is primarily guided by a set of laws. These laws are general and may not cover every specific case the court encounters. The judge must objectively apply these general laws to reach a judgment that is specific to the case at hand. In this context, the primary goal of the method is to achieve justice.

This example also highlights the issue of conflict of interest. To illustrate this, consider the difference between a judge's role and that of a prosecutor or

lawyer. A judge must remain neutral, with the objective of delivering justice based on existing laws. In contrast, a lawyer or prosecutor does not maintain neutrality, as their aim is to win the case, creating a clear case of conflict of interest.

Inductive research methods

The final category of research methods is inductive research. Induction refers to the process of moving from specific or simple observations to broader generalisations or laws. An inductive research method involves solving a problem or developing a general principle by starting with specific facts and observations.

Inductive research can be further divided into two subclasses, depending on how new knowledge is acquired. If the knowledge is derived purely through mental effort, without the use of physical tools, it is called mental induction. Examples of fields where mental inductive methods are applied include philosophy, logic, and mathematics. In these areas,

conclusions are reached on an abstract level, with no involvement of physical objects.

Conversely, if the knowledge is gained through physical efforts, such as experiments producing specific data, the method is called sensory induction, often used in applied sciences and engineering. Generally speaking, the common use of the term "research method" tends, if not specified, to refer to the inductive sensory approach.

Next, two examples of the inductive research methods will be discussed.

Example 1: Mathematics

In mathematics, research methods are entirely mental and inductive. For example:

$$0 + 1 + 2 + \cdots + n = \frac{n(n+1)}{2}$$

This equation reads as follows:

The sum of natural numbers from 0 to n is equal to n multiplied by (n+1), divided by 2

For n=3, the right side of the equation is:

$$0 + 1 + 2 + 3 = 6$$

The left side also is equal to:

$$\frac{3(3+1)}{2} = \frac{12}{2} = 6$$

This is a simple fact to start with. Next, an inductive research method will use this fact to show that the equation is valid for all natural numbers, creating a general law that applies to all possible values of *n* from the set of natural numbers.

It is important to note that the inductive research method used in this example is mental. All concepts involved are abstract, and the efforts required are purely cognitive.

Example 2: Physics

The second example pertains to physics, focusing on the question of which travels faster: sound or light?

A solid inductive research method will involve the following three steps:

1. Measure the speed of sound, thereby establishing the first simple fact.
2. Measure the speed of light to create the second simple fact.
3. Compare the two values and draw a conclusion, resulting in new and complex knowledge.
4. Repeat the experiment under different sets of controlled parameters to verify that the complex fact is repeatable and withstands testing.

It is worth to notice, that unlike mathematics, the inductive research method used in this example is based on physical tests in the real world. All concepts involved are tangible, and the efforts required are primarily practical, leading to empirical results. The goal is to establish a universal law that is consistently applicable.

Approaches

An approach refers to the overall strategy chosen to explore a question, solve a problem, or gain new knowledge. Methods can adopt various approaches, such as literary, promotive, or scientific, each influencing how data is generated or collected, how it is analysed, and the level of credibility it holds. Not all approaches are appropriate for research purposes, so it is crucial for researchers to understand which methods to avoid and the reasons behind those choices.

The literary approach emphasises creativity and imagination, commonly used in artistic fields. This approach is most effective when the content is open-ended or not specific. In literature, for example, ambiguity and the intentional use of words that can be interpreted in different ways are often encouraged. In this case, the writer is free to be subjective and express personal ideas.

The second approach is the promotive or advocacy approach. It combines logic with emotion, aiming to attract or persuade people, whether to buy a product, follow a religion, or support a political cause. However, this approach should be avoided in research, as a scientist must not allow personal bias to influence the study.

Finally, the scientific approach is grounded purely in facts. It is the essential method for conducting rigorous research. Here, the researcher must avoid vague terms like “a lot”, “several” or “many” and subjectivity is not allowed. Instead, objectivity is critical, and the researcher must follow the evidence wherever it leads.

The three approaches will be discussed in the remaining sections of this chapter.

Literary approach

The first approach to consider is the literary approach, which, as previously mentioned, focuses on creativity and aims to express personal emotions.

This approach is often used to convey moral lessons or to evoke emotional responses in the audience, such as making them laugh or cry. Works of comedy and tragedy typically follow this approach.

A key feature of the literary approach is its subjectivity. The same piece of work can be interpreted in various ways depending on the reader or viewer. For example, in cinema or novels, it is common to find contrasting reviews of the same work. This diversity in interpretation is not a problem but rather a natural outcome of engaging with literature.

The literary approach connects with human emotions and relies heavily on imagination. Since people have unique life experiences, their reactions to a piece of literature will vary, which explains the differing opinions often seen in reviews, especially in films or books.

The literary approach also relies heavily on indirect or implicit signs. In this case, the audience may miss or

misunderstand certain signs because they are not obvious. However, this is a natural aspect of the literary approach, and making everything direct is not a solution. It is acceptable, even expected, for the audience to fill in the gaps using their imagination.

The only real challenge occurs when the audience is completely unfamiliar with the subject or finds it too ambiguous to understand. Therefore, when using this approach, it is important to study the audience first. The ideas should be made clear enough for most people to grasp but still presented in an indirect way that requires some imaginative interpretation.

This approach is unsuitable for research methods, as it can lead to unclear results and subjective interpretations, which are not appropriate in scientific studies.

Promotive approach

The second approach to consider is the promotive approach. It focuses on both facts and emotions, with the primary goal of persuading people to adopt a

particular idea, as mentioned previously, it can be buying a product, subscribing to a service, following a religion, or supporting a political cause.

Unlike the literary approach, the promotive approach is grounded in facts. However, these facts are used strategically to achieve a specific outcome or to support a particular viewpoint by appealing to people's reasoning. At the same time, it can also engage emotions if that is more effective in reaching the goal. A solid promotive approach may even incorporate literary techniques. Simply, the end justifies the means.[66]

[66] This quotation is often attributed to Niccolò Machiavelli's The Prince (Latin: De Principatibus), published in 1532. Although it aligns with the book's philosophy, the phrase itself does not appear in the text. A potential source is Heroides (Latin: Epistulae Heroidum), written around 10 BCE by Publius Ovidius Naso (Ovid), a well-known Roman poet. In the second letter, titled “Epistula II (Phyllis to Demophoon)”, the phrase “exitus ācta probat” is used, meaning “The outcome justifies the deeds”. See p. 59 in [BKL01].

The primary focus of the promotive approach is not the validity of the idea being promoted, but rather the ability to attract a larger audience.

Methods that utilise the promotive approach tend to be subjective, making them unsuitable for scientific research. In science, it is essential for a researcher to maintain objectivity and to stay independent from the study being conducted.

Scientific approach

The final approach to discuss is the scientific. As previously outlined in this chapter the scientific approach relies exclusively on empirical evidence.

This approach depends on logic and reasoning to engage the audience, in contrast to the literary approach, which emphasises emotions, and the promotive approach, which combines both elements. The aim is not to attract followers or customers; rather, the key focus is on the validity of the results, regardless of whether individuals believe them or not.

Scientific approaches can be classified into qualitative or quantitative, depending on the type of data they utilise.

Qualitative approaches may encompass emotions or behaviours, with the primary aim of examining complex concepts, such as social interactions or cultural phenomena. This subclass is typically employed to investigate how, or why, certain events occur and to explain occurrences or describe human actions. It is often linked to descriptive methods and is widely used in the humanities and linguistics.

Conversely, quantitative approaches are of numerical nature, where handled data can be organised, ranked, or measured along a specific scale. The main objective of employing this approach is to identify patterns or relationships between variables, answering questions that begin with terms such as “how many”, “how much”, or “how often”. This approach is generally associated with the inductive

method and is frequently applied in the natural sciences.

Understanding the distinction between quantitative and qualitative approaches in scientific methods is crucial. The differences become evident when comparing the methods of data collection and the nature of the data obtained (Table 3-1).

The initial focus will be on how to generate data using both quantitative and qualitative approaches.

In the quantitative approach, surveys are often used. A survey provides a broad overview of a person or situation, consisting of closed questions with limited answer options, typically in numerical form. These surveys can be distributed to hundreds or thousands of respondents. In contrast, qualitative approaches usually involve conducting interviews with specific individuals. These interviews feature open-ended questions, allowing for a wide range of possible answers. In some instances, discussions may also take place instead of structured interviews.

Both quantitative and qualitative approaches involve observation, but they produce different types of data. For instance, when observing a herd of domesticated animals in their natural environment over a week, the quantitative approach would concentrate on aspects such as the number of animals in the herd, how often they eat, and their sleep patterns. Conversely, the qualitative approach would focus on the social dynamics within the herd, such as identifying the alpha male and documenting his behaviour towards other animals.

The treatment of documents varies depending on whether quantitative or qualitative approaches are employed. For instance, when analysing a series of messages exchanged between two individuals, a quantitative approach seeks numerical data: How many messages were exchanged? When were they sent? How many words are contained in each message? What is the average word count? Conversely, a qualitative approach examines the

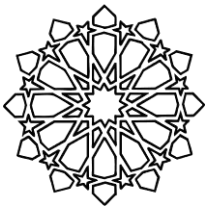
nature of the messages, the relationship between the two individuals, the writing style, and other contextual factors.

Table 3-1. Comparison between quantitative and qualitative tools used to obtain data

Criteria	Quantitative	Qualitative
Data generation	**Surveys**: Closed questions (set of answers) - large number - numeric data	**Interviews**: Open questions & discussion - limited group - extract descriptive details
Use of observation	obtain numbers, frequencies, statics	Monitor Behaviour, roles, needs
Documents treatment	**Screening**: in search for numerical data	**Analysis**: Focus of the style of the writer
Tests	**Conducting experiments:** physical tests and recording	**Recording life stories:** Remembrances, memories and experiences

Finally, from a quantitative standpoint, physical tests can be performed, and results can be documented in numerical format. In contrast, from a qualitative perspective, experiences may be conveyed through personal narratives, such as memories and reflections.

Another example highlighting the differences between the two scientific approaches is the collection of personal data through questioning. Quantitative data could include metrics such as age, weight, height, shoe size, and annual income. Conversely, qualitative data might encompass information such as name, gender, languages spoken, and educational background.



Scientific method

Introduction

In Chapter 3, research methods were defined as the strategies, processes, or techniques used to collect data or evidence for analysis, with the aim of discovering new information or gaining a better understanding of the subject being studied.

Within this context, a method is considered scientific if it is systematic and testable. Systematic means that the method must follows a well-defined ordered set of steps that can be consistently applied without exceptions. And testability means that a subject can always be examined to verify its validity.

Building on that, chapter 4 will focus on the scientific method. The chapter is divided into three main sections. The first will briefly discuss how science is characterised. The second section will introduce the scientific method, detailing its structure, highlighting its importance, and explaining how to apply it

effectively. Finally, the third section will explore the key properties of the scientific method, which are crucial for distinguishing science from non-science.

What to consider a science?

Properties of the science

From a philosophical standpoint, science is far more complex than simply being defined by systemacity and testability. To classify a field of knowledge as science, it must meet six essential criteria:[67]

- **Well-defined terminology,** it is essential for a science to have a specific term referring to a precise concept and allow only one interpretation of the definition. This is why specialised dictionaries are created for each branch of knowledge.

[67] More on this subject in [WEB03], an article published in 2013 in the Scientific American Journal, written by Ashutosh Jogalekar, titled: “Is psychology a “real” science? Does it really matter?”.

- **Quantifiability**, A science must deal with measurable quantities, requiring a clear standard system of defined units. This is why scientific fields always focus on quantities and measurement units. For example, psychology examines human behaviours and instincts, such as fear, which are not quantifiable. As a result, psychology is often debated as not being considered a science. Referring to [WEB3], an article written specifically to address whether psychology qualifies as a science. While this topic remains debated, the prevailing view among most scientists today is that psychology is not a science.
- **Highly controlled experimental conditions**, Science must be grounded in expertise, and that expertise needs to be carefully regulated. This requirement means that fields relying primarily on descriptive methods are not considered scientific. This is why disciplines

like social sciences, history, and religious studies face challenges when it comes to determining whether they can be classified as sciences.[68]

Another example is geography and geology. While geography, as a field of study, primarily employs descriptive research methods to examine the Earth, geology utilises inductive methods. Consequently, geology qualifies as a scientific discipline that investigates the composition and structure of the Earth.

- **Reproducibility**, it means that anyone following the same method or steps should achieve the exact same results. While this may seem straightforward, it is actually one of the most difficult criterion to meet. For instance, many argue that economics lacks

[68] These branches of knowledge could meet this criterion if the knowledge acquired is based on empirical observations and can be verified by other researchers operating under the same conditions. “Empirical” refers to knowledge derived solely from sensory experiences.

reproducibility because it involves human factors, which cannot be predicted with complete certainty. This is why some theorists and philosophers do not consider economics a science.[69]

In this context, it is essential to distinguish between reproducibility and replicability.[70] Reproducibility refers to the ability to repeat a particular study or experiment under the same conditions and consistently achieve the same results. This ensures the research method's reliability and validity. Replicability, on the other hand, allows other researchers to replicate a study or experiment using the

[69] Regarding the issue of reproducibility, refer to [ARE02] and [ARE03] for further details. Economics, in particular, has faced ongoing criticism for not being considered a science. This is due to several factors, including challenges with verifiability and the reliance on overly simplified assumptions. For more information, see p. 30 in [BKE11], [ARE04] and [ARE05].

[70] For further information on the distinction between the two concepts, refer to the article published by the Leibniz Information Centre for Economics [WEB04] and [BKE12].

same research method but in different circumstances. This tests the validity of the findings.

In short, reproducibility relies on the original data, materials, and protocols, whereas replicability verifies the results under varied conditions using the same method.

- **Predictability**, it means that a science must be able to forecast future data based on current and past data or calculations.

  It is crucial to understand that this is not fortune-telling, as all predictions must be testable. For example, astronomy[71] can accurately determine the exact position of the moon as seen from any location on Earth at midnight. The prediction will always work because it is based on precise calculations, not chance or luck.

[71] Astronomy is the scientific study of celestial bodies, and it should not be confused with astrology, a pseudoscience that makes predictions based on the observation of these bodies.

- **Testability**, this means that all claims or hypotheses in science must be verifiable, at least from a theoretical standpoint. In some cases, it may not be possible to test these claims empirically due to a lack of necessary technologies, leaving them untested for decades.

  For example, in Chapter 2, Albert Einstein's prediction that massive objects can distort time was highlighted. This was a testable claim, at least theoretically, but when it was proposed, there were no tools available to measure and verify it. As a result, the claim remained untested for nearly a century.

A field of knowledge must meet all the criteria outlined above to be classified as a science by definition.[72]

Modern classification of sciences

The term "science" is often associated with inductive research methods, particularly in applied fields like physics, chemistry, and engineering, where observations from controlled experiments are more feasible. However, science is not restricted to applied disciplines.

[72] This is not the only way to define science. There are other approaches. For example, criteria, known as the Mertonian norms, were proposed by Robert K. Merton (1910-2003) in his 1942 essay titled "The Normative Structure of Science". According to Merton, science is guided by four key principles, often summarised by the acronym CUDOS: (1) Communism, referring to the shared ownership of scientific discoveries; (2) Universalism, meaning scientific claims should be evaluated based on universal principles, not personal biases; (3) Disinterestedness, which expects scientists to prioritise objectivity over self-interest; and (4) Organised Skepticism, meaning that all ideas must undergo rigorous testing and critical evaluation.

In this regard and broadly speaking, modern consensus divides science into two main categories: formal sciences and empirical sciences.[73]

Formal science deals with abstract structures like algorithms, shapes, solids, and both formal and natural languages. Since it is non-empirical, new knowledge is acquired through reasoning rather than observation. Formal science can be further divided into two classes: foundational and applied. Foundational formal science focuses purely on theoretical aspects, such as logic and pure mathematics. In contrast, applied formal science involves the practical application of these theories, covering areas like computer science and applied mathematics.

Empirical sciences rely on sensory experiences or experimental methods. They are classified into natural and social sciences, depending on the field of

[73] Refer to p. 14-41 in [BKE13].

application. Natural sciences aim to describe physical systems, while social sciences focus on human societies, cultures, and the relationships between individuals within those societies.

As with the Formal sciences, both natural and social empirical sciences are divided into foundational and applied based on the same criteria discussed before. examples regarding the four subclasses of Empirical sciences can be found in Table 4-1.

Table 4-1: Classification of modern sciences

	Formal	**Empirical**	
		Natural	**Social**
Foundational	Logic	Physics, chemistry & biology	Economics & sociology
Applied	Computer science	Engineering & medicine	Anthropology archaeology

Non-Scientific paradigms

With all the criteria discussed so far, the distinction between what qualifies as science, and what is not, becomes evident. Any process or discipline that fails to meet these conditions is classified as pseudoscience.[74]

According to the National Science Foundation (USA), pseudoscience is defined as:[75]

> *"Claims presented so that they appear [to be] scientific even though they lack supporting evidence and plausibility"*

However, the range of pseudoscience is quite broad. It includes practices that are widely regarded as

[74] Pronounced /ˈs(j)uːdəʊˌsʌɪəns/, with a silent P. Pseudo- is a suffix from a Greek origin, it means false, erroneous or in appearance only.

[75] This definition can be accessed on the Foundation's webpage [WEB05] and was originally stated on p. 17 in [BKE14].

invalid, such as Phrenology,[76] as well as those often associated with conspiracy theories, like Ufology.[77] Additionally, most practices involving religious beliefs, such as Creationism,[78] are also classified under pseudoscience.

Another category of claims that falls outside the realm of science is known as fringe theories. They can vary in their levels of academic acceptance. However, they share a common characteristic of being outside the mainstream academic consensus on the subject in question. Typically, fringe theories do not adhere

[76] Derived from the Greek "φρήν" (Romanised: phrēn), meaning "mind", and "λόγος" (Romanised: logos), meaning "study". Phrenology is a set of measurements claiming to predict mental traits based on physical characteristics, particularly the shape and bumps of the skull. It is considered pseudoscience due to its lack of a clear and coherent methodological framework.

[77] UFO stands for Unidentified Flying Object, and Ufology is the study of these phenomena, often conducted by individuals who believe extraterrestrial beings frequently visit Earth. It is considered pseudoscience due to the absence of supporting evidence and its lack of falsifiability.

[78] Creationism is a religious belief that attributes the origin of the universe to a supernatural or divine act of creation. It is classified as pseudoscience due to its reliance on religious texts and the absence of empirical evidence to support its claims.

to valid methodological standards and are often built on exaggerated assumptions. Examples of fringe theories include conspiracy theories related to vaccinations during the COVID-19 pandemic[79] and pseudohistorical narratives.[80]

In this context, it is essential to distinguish between alternative theories and fringe theories. An alternative theory is a concept or claim that is developed using a solid methodological foundation but remains theoretical, with no known means to test or verify its validity. One example of this type of claim is the theory of continental drift. The idea that

[79] The claims regarding the side effects of vaccinations during the COVID-19 pandemic were never broadly accepted within the academic community due to a lack of supporting evidence. It was also difficult to disprove these claims for the lack of evidence as well. Nevertheless, the prevailing academic consensus has always supported the use of vaccinations.

[80] Pseudohistory refers to a collection of practices aimed at distorting the historical record. It encompasses a wide range of claims, including the assertion that Islam was not founded in the Arabian Peninsula but in the Levant, as well as the claim that Adolf Hitler did not commit suicide at the end of World War II, but instead escaped Berlin and lived for decades afterwards.

continents have moved over time dates back to the late 16th century, but it was refined and fully articulated by Alfred Wegener[81] in his 1915 booklet titled: “The Origin of Continents and Oceans”.[82]

When the theory of continental drift was first proposed, it was not widely accepted within the scientific community. The issue did not lie in the method Wegener employed to develop his claims, his approach was valid. However, there was no identified mechanism to explain the force driving the movement of continents. Furthermore, Wegener estimated the rate of drift to be 250 cm per year, which was later found to be an overestimation by a factor of 100, as the actual average rate is

[81] Alfred Lothar Wegener (1880-1930), a German geophysicist well-known for his polar research and for reformulating and promoting the theory of continental drift within the field of geology.

[82] The book was published in German at Braunschweig. The original title was (German: Die Entstehung der Kontinente und Ozeane), See [BKG01].

about 2.5 cm per year. In summary, the theory remained unaccepted for 40 years.

By 1950, increased research in oceanography [83] led to the discovery of new evidence that strongly supported Wegener's claims. Consequently, twenty years after his death, the theory of continental drift began to gain acceptance and eventually became the dominant perspective in geology by the late 1960s.

In conclusion, Table 4-2 presents a comparison of alternative theories, fringe theories, and pseudoscience based on their respective characteristics.

[83] For further information on the discoveries made on the ocean floor, refer to [ARE06] and [ARE07].

Table 4-2. Comparison of non-scientific paradigms

	Alternative theories	**Fringe theories**	**Pseudo-science**
Properties	(1) Solid method (2) Cannot be tested	(1) Problems with method (2) Not accepted widely	(1) Invalid method (2) Lack of empirical evidence
Examples	Continental drift	Pseudohistory	Astrology

Understanding the scientific method

Structure

Since the establishment of modern science, the understanding of the scientific method within various fields has evolved significantly, producing a quite sophisticated process.

Unfortunately, there is no single, universally accepted definition of the scientific method. However, across different scientific disciplines, most methods that meet scientific standards share common steps and a cyclical process (Figure 4-1).

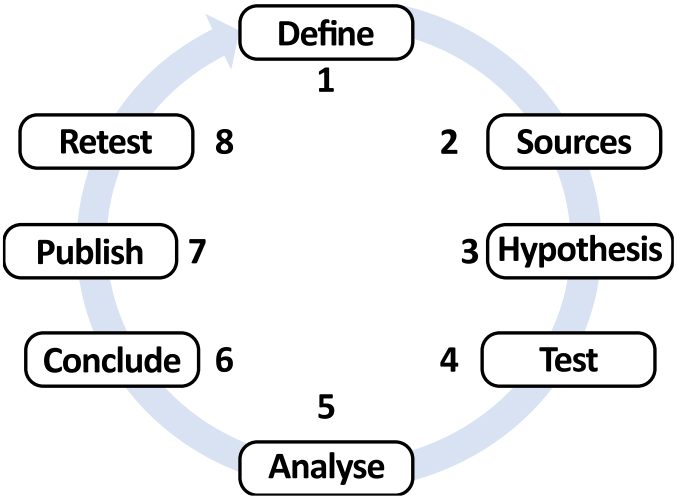


Figure 4-1. The scientific method

To provide an overview of the scientific method, this section will briefly outline an eight-step research process, followed by a more detailed exploration of each step.

1. The first step involves defining the problem. Identifying a specific problem or unanswered question is crucial, as the research, guided by the scientific method, seeks to address or resolve it.

2. The second step, often referred to as the “state-of-the-art”, involves reviewing the current knowledge and developments related to the problem. This step requires examining available sources to build an understanding of the problem being addressed.
3. In the third step, a hypothesis is formulated based on the insights gathered in the second step. A hypothesis is a proposed solution or explanation for the problem, but at this stage, it is still an unverified claim that requires further testing.
4. The fourth step involves testing the hypothesis. At this stage, the researcher designs an experiment or way to assess the validity of the hypothesis. Before conducting the test, the type of data to be gathered must be clearly defined. The experiment is then carried out, and data is collected accordingly.

5. The fifth step starts once the test is completed, the collected data undergoes analysis. This involves organising the data to identify any patterns or trends and understand why do they appear.
6. In the sixth step, the analysis results provide the researcher with a broader understanding of the case being studied. This understanding aids in drawing a clear conclusion:
    a. If the problem is solved or the results are well-supported, the researcher may proceed to publish the findings.
    b. If the problem remains unsolved, the researcher returns to Step 3 to develop a new hypothesis.
7. Publishing, the seventh step, is crucial yet often undervalued. Sharing results through publication allows other researchers to access and review the findings. It serves as the means of communication, and the more

openly accessible publications are, the larger the audience is, and the faster human knowledge can advance.

8. Finally, the retesting phase occurs in Step 8. This step is typically carried out by other researchers who re-examine the hypothesis and verify the original results to ensure their accuracy and validity.

Before exploring each step in detail, two key insights can be drawn from the previous overview:

1. The scientific method is an ongoing process, reflecting the continuous evolution of scientific knowledge.
2. The method follows a circular structure, meaning there is no definitive starting point.

In the next section, each step will be discussed in greater depth.

Defining the research problem[84]

The first step of the scientific method focuses on defining the research problem in the form of a question, which the research aims to answer. The research question should be as clear and specific as possible. It is essential for researchers to understand that solving all problems within a field is not achievable in a single study. Instead, the aim should be to focus on a narrow, well-defined issue and attempt to address it.

The research question can be either open or closed. It is important not to confuse “narrow” with “open”. In this context, “open” refers to a wide range of possible answers, while “narrow” pertains to the specificity of the question itself.

For example, when studying dark matter or extraterrestrial life, the limited available data may justify using an open-ended question. In contrast,

[84] This subject will be focusing the of Chapter 5, refer there for more details.

research on a specific property of a chemical element usually involves a more restricted set of possible answers, given the extensive existing knowledge in the field.

A key aspect of this step is that the research question must build upon the work of others, as starting from scratch is not a recommended option. Instead, the research should begin where previous studies have left off. This highlights the cyclical nature of the scientific method. In fact, the starting point could even originate from Step 8: the retest, or from Step 2: the state-of-the-art, where the research question may be significantly refined based on new findings.

Defining a research question is often the most challenging step in the scientific method and has a significant impact on all subsequent steps. Therefore, it is vital for early-career researchers to seek guidance from more experienced colleagues.

Conducting a state-of-the-art[85]

The second step is known as the state-of-the-art, a technical term referring to the most advanced or leading developments in a particular field. This stage involves understanding the current state of human knowledge concerning the research problem at hand.

It is essential for researchers to be aware of the latest advancements in their area to ensure they do not tackle a problem that has already been solved. Avoiding the duplication of existing research is vital for conserving effort, time, and resources.

This step relies entirely on reliable sources. The researcher might begin with a research question in Step 1, and then, seeks out published works in trustworthy sources. Typically, this stage involves exploring the details, leading to a refinement and

[85] Chapter 6 address this subject in detail, check there for more details.

reformulation of the research question to incorporate the newly acquired insights.

At this step, it should be expected to handle a large amount of information that need to be organised and analysed to maximise its value. The findings from this phase generally form the first chapter or section of the final report or thesis.

The outcome of this step is a revised version of the research question picked up in Step 1.

Formulating a hypothesis

The third step in the scientific method involves formulating a hypothesis[86], which is a proposed explanation to be tested. In essence, any problem presents potential solutions or answers. However, due to constraints of time and cost, it is often impractical to test all possible answers. A reasonable

[86] Hypotheses were discussed in detail in Chapter 2, refer to that chapter for further information

approach is to select one solution or combine two into a more general hypothesis for testing.

The selection of answers to be tested is not arbitrary. An experienced researcher can eliminate corrupted answers or those that lead to dead ends based on prior knowledge and experience. This underscores the importance of having a mentor or supervisor for early-career researchers, who can guide, support, and validate the research process at every stage.

In earlier chapters, when comparing hypotheses to theories, emphasis was placed on the notion that a hypothesis is closely aligned with physical reality, focusing on measurable objects. This distinction is significant because physical objects can be tested, whereas abstract concepts cannot be easily evaluated. Therefore, a hypothesis should avoid dealing with abstract concepts, as this is crucial for the subsequent step: the testing phase.

Building a test

The fourth step involves designing a test or constructing an inquiry to gather data regarding the proposed hypothesis. At this stage, it is crucial to identify which parameters need to be measured, how they will be measured, and to predict the expected range of results. These expected values are often derived from existing theories.

Once the test is performed and data is gathered, several outcomes are possible:

- The results may match the expected values exactly, which is quite rare, particularly for a first-time test. In such cases, it is strongly recommended to repeat the earlier steps to rule out any biases or manipulation. Occasionally, researchers may unknowingly influence the test to produce results that align with their expectations. If this happens, the findings are invalid, and the process cannot be considered genuine research. It is vital for the

researcher to remain completely objective and avoid manipulating the results in any way.

- Alternatively, the results might deviate from the expected values but still fall within an acceptable range. This can actually be promising. It suggests that something may have been overlooked, or perhaps one or more parameters were not properly calibrated. In this case, the researcher should analyse the results, make necessary adjustments to the method or test, and then repeat the process.
- In some cases, the results may be entirely corrupted, with values that fall completely outside the expected range and do not fit within the scope of the research. This usually indicates that the method or test is unreliable, requiring a significant revision.

Regardless of the outcome, researchers must proceed to the analysis and conclusion stages (Step 5

and Step 6). These steps are needed for learning from any mistakes, identifying the problems, and refining the test for future iterations.

At this stage, it is important to remember that science is as much about the process as the outcomes. In some cases, it can be valuable for researchers to publish invalid results, explaining why the results are not reliable and offering suggestions for improvements. This practice helps other researchers avoid making the same errors, ultimately saving time, cost, and effort by eliminating dead-end methods. Unfortunately, not all researchers follow this approach.

Analysing of the collected data

This is the fifth step of the scientific method. First, the gathered data needs to be classified and sorted. As discussed in Chapter 3, classifying refers to grouping data into different categories, such as dates, names, or links. Sorting then involves arranging the data within each group, either in ascending or descending

order, or chronologically. Additionally, it may be necessary to remove duplicate or corrupted data to ensure validity.

Secondly, the tools used for analysis will depend on the type of data collected. If the data is quantitative, statistical approaches will be applied. For qualitative data, it should be organised using scales to identify patterns or notable behaviours.

Before beginning data analysis, the researcher must remain objective and avoid steering the results in any particular direction. Instead, the researcher should maintain a neutral stance towards their own research.

The primary aim of analysis is not merely to compare the collected data to the expected values but to understand why it aligns, deviates, or matches exactly. If the results are identical to expectations, the researcher should approach this with caution and seek to understand the reasons behind it. If there are

differences, it may indicate something was overlooked or a parameter that needs adjusting.

These questions should be addressed during the analysis step. It is vital that the researcher works methodically, avoiding hasty conclusions. Analysis should be grounded in facts, data, and evidence, proceeding step by step with an inductive method.

Drawing conclusions

The sixth step of the scientific method involves drawing conclusions. The researcher must remain objective during this stage and avoid manipulating the results to fit expectations. If the results differ significantly from what was anticipated, it should not be seen as a personal failure. Instead, the researcher must maintain a neutral perspective throughout the process, focusing on the findings rather than personal expectations.

Once conclusions are reached, the researcher must decide on the next step, considering factors such as

available time and budget. There are two possible directions:

- Return to Step 2 or Step 3 to refine the research question or explore new potential answers to test.
- Move on to Step 7, where the results will be prepared for publication.

As mentioned earlier, there is no problem with publishing findings based on an invalid hypothesis. This can be valuable for other researchers. The key is to present the results accurately, explaining that the hypothesis was tested but did not succeed for specific reasons. It is also important to propose improvements or alternative approaches to refine the hypothesis. This way, those who wish to build on the work have an well-structured starting point.

Publishing

If the results are suitable for publication, the next step is Step 7 of the scientific method. There are

several important factors to consider before proceeding with publication:[87]

- Scientific publishing involves a process known as peer review, where other experts in the same field evaluate the research and verify its validity. This process results in one of three possible outcomes:
    a. The work is accepted and published without changes.
    b. The work is accepted, but the author is asked to make revisions or corrections.
    c. The work is rejected.

    If the work is rejected, the researcher should not take it as a personal failure. Rejection indicates that there is an issue with the research. Usually, the rejection comes with

[87] In this context, publishing refers specifically to peer-reviewed journal articles. However, other forms of publication also exist, such as reports and books. For more information on these, refer to Chapter 8.

feedback from the reviewers, allowing the researcher to identify the problem and make improvements.

- To publish the results, they must be documented in a structured and organised manner:
    a. General context of the research
    b. Description of the problem
    c. State-of-the-art
    d. Proposed solution
    e. How to test the proposed solution
    f. Obtained results.
    g. Analysis
    h. Conclusion and future work.

  Almost all scientific research follows this specific structure, and to successfully publish, this structure must be adhered to.[88]

[88] Further details on the structure of academic articles will be discussed in the next chapter and in Chapter 8.

- The next step is to decide the appropriate medium for publication. Will it be presented at a workshop, a meeting focused on the topic, a conference related to the subject, or submitted to a scientific journal? Each of these options has its own specific requirements that must be followed.

Retesting

Finally, the last step in the scientific method, Step 8, is retesting. Once the work is published, other scientists have the opportunity to retest and validate the findings. This can serve as a foundation for additional research. Building on the published study, these researchers may identify new problems and initiate their own investigations.

When individuals read published research, it serves as an indirect form of communication between the authors and the readers. In many instances, this communication can become direct, as scientists often reach out to one another via email, typically found at

the top of the published work. Such correspondence usually involves the exchange of ideas or consultations.

Properties

The scientific method is characterised by several key properties, which collectively render it a distinctive approach to generating reliable knowledge.

As this research method is termed “scientific”, it is not surprising that many of its characteristics are derived from established scientific principles, which were discussed earlier in this chapter. In the upcoming sections, the following properties will be explored: reproducibility, predictability, systematicity, skepticism, objectivity, and reliability.

Reproducibility

Reproducibility, often referred to as repeatability, is a fundamental characteristic of the scientific method. Both terms share the prefix “re-”, which indicates

that the action associated with the root word will occur again.

This is essential for the scientific method. When the same method is applied under identical conditions, the results should consistently be the same. Whether it involves an experimental observational study or a statistical analysis, achieving the same outcomes every time is essential. If the results vary, then the method used to reproduce the findings cannot be considered scientific.

Power posing[89] serves as an example of how the inability to achieve reproducibility can undermine a method's validity. About a decade ago, a claim was made suggesting that anyone could enhance their mental state by standing in front of a superhero poster while giving a speech. Although this may seem naive, it was taken seriously. Numerous studies were

[89] The original claim was published by Dana R. Carney, Amy Cuddy, and Andy Yap in a peer-reviewed scientific journal in 2010, see [ART08].

conducted in an attempt to scientifically validate this technique, but the results varied largely with no evidence of an impact.[90]

Figure 2. Amy Cuddy presenting power posing at PopTech Conference 2011 (Camden, Maine)

As a result, this technique did not yield consistent findings when carefully tested, indicating that it failed the reproducibility test. Consequently, it is regarded as a non-scientific claim.

[90] Check for examples [ARE09], and [ARE10].

Predictability

It means the ability to forecast outcomes using both current and past data.

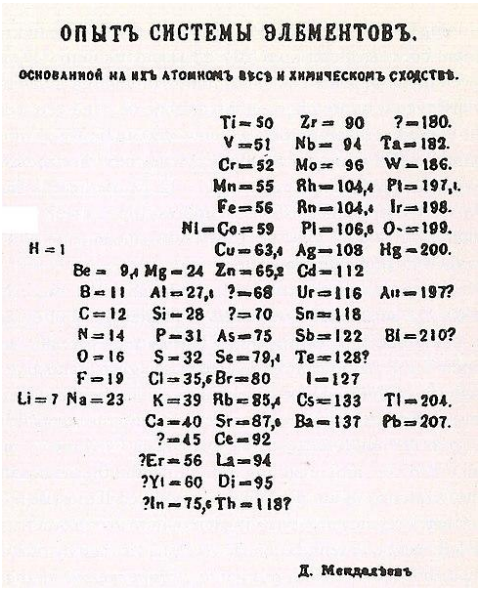
For example, when Dimitri Mendeleev[91] discovered the periodic trends[92] of the chemical elements formulating the periodic table in chemistry, he predicted the existence of yet-to-be-discovered elements to fill many gaps he had in the table. He also anticipated some properties of these elements based on the trends and known elements.

This is not astrology or fortune-telling. Mendeleev's predictions were grounded in scientific evidence. He did not foresee undiscovered elements based on personal beliefs or spiritual experiences. Instead, Mendeleev thoroughly studied the known chemical

[91] Dmitri Ivanovich Mendeleev (Russian: Дмитрий Иванович Менделеев) (1834 - 1907) a Russian chemist, renowned for his development of the periodic table of chemical elements.

[92] These are specific patterns of chemical elements that vary systematically according to their atomic properties. The key trends include atomic radius, ionisation energy, and electronegativity.

elements and observed that they could be arranged in a periodic manner, allowing the properties of elements to be predicted based on their position in the table.



ОПЫТЪ СИСТЕМЫ ЭЛЕМЕНТОВЪ.

ОСНОВАННОЙ НА ИХЪ АТОМНОМЪ ВѢСѢ И ХИМИЧЕСКОМЪ СХОДСТВѢ.

			Ti = 50	Zr = 90	? = 180.	
			V = 51	Nb = 94	Ta = 182.	
			Cr = 52	Mo = 96	W = 186.	
			Mn = 55	Rh = 104,4	Pt = 197,1.	
			Fe = 56	Ru = 104,4	Ir = 198.	
			Ni = Co = 59	Pl = 106,6	Os = 199.	
H = 1			Cu = 63,4	Ag = 108	Hg = 200.	
	Be = 9,4	Mg = 24	Zn = 65,2	Cd = 112		
	B = 11	Al = 27,4	? = 68	Ur = 116	Au = 197?	
	C = 12	Si = 28	? = 70	Sn = 118		
	N = 14	P = 31	As = 75	Sb = 122	Bi = 210?	
	O = 16	S = 32	Se = 79,4	Te = 128?		
	F = 19	Cl = 35,6	Br = 80	I = 127		
Li = 7	Na = 23	K = 39	Rb = 85,4	Cs = 133	Tl = 204.	
		Ca = 40	Sr = 87,6	Ba = 137	Pb = 207.	
		? = 45	Ce = 92			
		?Er = 56	La = 94			
		?Yt = 60	Di = 95			
		?In = 75,6	Th = 118?			

Д. Менделѣевъ

Figure 4-3. The first version of the periodic table of chemical elements (1869) by Mendeleev, with '?' indicating predicted elements[93]

In every case, a scientific prediction or hypothesis must be tested and verified. For instance, in

[93] This image is a scan from Mendeleev original work, as it appeared in the May 1869 edition of the Journal of the Russian Chemical Society.

Mendeleev's case, scientists began searching for chemical elements with the properties he predicted, and they eventually confirmed his claim. However, verifying certain predictions can be challenging due to technological limitations. Albert Einstein's prediction about gravity, previously discussed in Chapter 2, is an example of such a challenge.

Systemacity

It refers to being methodical, meaning following a clear, organised approach with well-defined, detailed steps, leaving no room for ambiguity.

In scientific research, an ordered process must be established logically, with justifications for every decision made. This ensures that the researcher can explain why a particular method was chosen over another. This also implies that choices should not be random or based on chance, which is why the phrase “well-defined steps” has been frequently emphasised. The researcher must carefully define the concepts, processes, and units used to measure

quantities. Without a systematic approach, reproduction and prediction cannot occur, as both require a structured system to function effectively

An example of the systematic nature of the scientific method can be seen in the classical three impossible constructions of Euclidean geometry.[94] These are:

1. Trisecting an angle, which means dividing an angle into three equal parts.
2. Squaring the circle, or drawing a square with the same area as a given circle.
3. Doubling the cube, which involves constructing a cube with twice the volume of a known cube.

With current mathematical knowledge, it has been proven that these problems cannot be solved using Euclidean geometry alone. Since geometry adheres

[94] In geometric constructions, only a compass and a ruler are permitted. The compass is used to draw circles, while the ruler is used to draw straight lines, but it cannot be used to measure distances.

to a structured and well-defined scientific method, ancient mathematicians could not find solutions or bypass the challenges. It is important to emphasise that the rules governing the method must not be altered when obstacles arise, which is why these problems, first posed by the Greeks centuries before Christ, remained unsolved until the mid-19th century.

Skepticism

It means examining all claims and theories at least once before accepting them.

Skeptics, or those who practice skepticism, have formed an association and defined it as:[95]

"The application of reason to any and all ideas"

---

[95] The group is known as The Skeptics Society, more information can be found on their website: https://www.skeptic.com/. The definition provided comes from their official page: https://www.skeptic.com/about_us/.

In this context, skepticism involves evaluating ideas based on whether they can be verified and falsified. For an idea to be accepted, it must first be proven valid, with no consideration given to personal beliefs or unreliable sources or evidence.

Descartes, introduced in Chapter 1, emphasised doubt as a foundation of the scientific method. As a result, this approach became known as Cartesian doubt, named after him. In the first step of his method, Descartes advised never to accept anything as true unless it is proven to be so. He also urged researchers to avoid precipitancy and prejudice[96], which directly reflects the principles of skepticism.

Objectivity

This means that results obtained through the scientific method are based solely on solid scientific

[96] The original text reads (French: Le premier étoit de ne recevoir jamais aucune chose pour vraie que je ne la connusse évidemment être telle), see p.141 in [BKF01].

facts, not influenced by the researcher's personal opinions, emotions, or cultural biases.

Bias is a natural part of human behaviour and can find ways to any step of the scientific process: whether in formulating the research question, creating the hypothesis, designing the experiment, collecting or analysing data, or publishing the results. To minimise bias at each stage, there are specific guidelines that must be followed. This adds complexity to the method, which is why each step must be defined in detail.

For example, in clinical studies, a technique called "double-blind" is used to avoid bias and ensure objectivity. In this method, patients are divided into groups, and treatments are administered randomly. Neither the patients nor the doctors know who is receiving the actual treatment, hence the term "double-blind." However, the researcher overseeing the study is aware of the treatment allocation. This approach prevents any potential influence from

patients' expectations or doctors' biases on the study's results.

Reliability

In this context, reliability refers to the trustworthiness of scientific work, meaning how much it can be depended upon as valid. The scientific method ensures reliability through a process known as peer review. This involves the review of the research by an independent body, separate from the scientists who conducted it.

The peer review process includes three key participants (Figure 4-4):

- The author or researcher.
- The entity responsible for reviewing the work.
- The audience, typically other scientists, who will read the final published results.

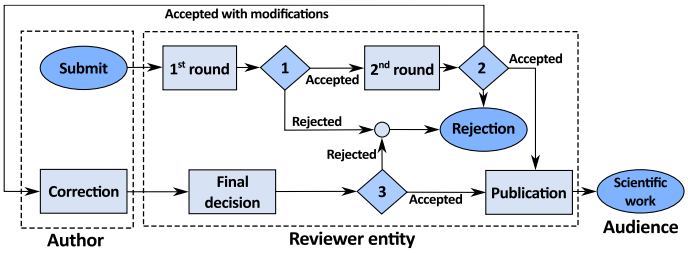


Figure 4-4. The peer-review process

The process begins with the author, who prepares and submits his findings in the form of an article to a reviewing entity. Initially, technical editors evaluate the submission for validity. If the article does not meet the necessary criteria, it is rejected. However, if it passes this stage, it proceeds to a second review, where peers: fellow scientists in the same field, examine the work and provide feedback:

- If the work is deemed valid, it moves directly to publication.
- Often, reviewers may accept the work but request modifications or corrections, which are sent back to the author.
- In some cases, if the work is found invalid, it will be rejected.

If the article is returned to the author with requests for modifications or corrections, the author must incorporate the feedback into their work and resubmit the revised version to the reviewers. An editorial board will then evaluate the author's response to the suggested changes:

- If the response meets the required modifications, the article will be accepted and move on to the publication stage.
- If the response is unsatisfactory, the article will be rejected.

Once the article reaches the publication stage, it becomes available to the public.

The peer-review process, which relies on a well-organised and skilled entity, ensures that published work is trustworthy and reliable.

The peer review process is lengthy, typically taking between three to nine months from submission to publication, depending on the article's review path. It

is also costly, with authors usually paying the publishing entity only if their paper is accepted. The expenses arise due to the complexity of the system, which requires funding to operate efficiently.

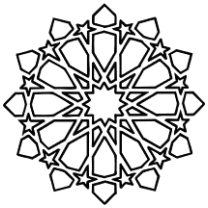
However, peer-review model has sparked significant debate, as it does not offer equal opportunities to all countries or research institutions. The high cost can present a major barrier. While there have been efforts to develop alternative models, none have been successful enough to replace the current system.

With the widespread availability of the Internet, a new threat to the reliability of the scientific method has emerged: predatory journals.[97]

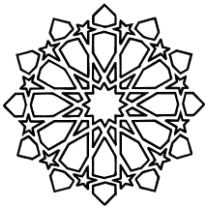
These are publications run by entities that claim to follow the standard peer-review process but, in

[97] Also known as predatory publishing, this term was introduced by Jeffrey Beall (196? -) in 2012 [ARE11]. It is estimated that thousands of scientific articles are currently being published without undergoing a proper peer-review process. For more information, see [ARE12].

reality, do not. Their primary concern is collecting fees, and they often publish nearly any submission, regardless of its validity.[98]



[98] There are several up-to-date databases that track predatory journals worldwide, most famously Cabells' Predatory Reports and Kscien's list, See [WEB06]. However, the lists themselves were criticised for using statistical data only and lacking evidence when classifying. See [ARE14] and [ART15].



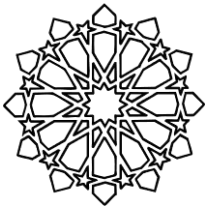
PART II: On the scientific method

Ch. 5 On the research problem

Ch. 6 On the sources

Ch. 7 On the ethics of research

Ch. 8 On writing and publishing



On the research problem

Introduction

Researchers are pioneers in their fields, taking the initial steps on behalf of humanity to advance knowledge. This is why working in the early stages of research, where problems, boundaries, and possibilities are defined, is always a complex and demanding task.

In Chapter 4, the scientific method was outlined as an eight-step process. While the method follows a circular pattern, the starting point typically centres around the research problem. The researcher may either focus on identifying a new problem or work on one that has already been described.

This chapter focuses on exploring the research problem and guiding researchers in identifying one. First, essential skills for tackling research challenges will be introduced, including selective reading and effective reference management. The chapter will

then address how to define the research problem in terms of its context and structure. Finally, the key characteristics of a well-defined research problem will be outlined.

Basic skills

There are some essential skills that when applied, help define the research problem more effectively. While these skills are not strictly required for achieving solid results, they can significantly accelerate the process, saving both time and effort.

This section begins by examining the structure of research studies. Then, it introduces selective reading, a method for quickly extracting the key information from scientific works relevant to the research. Finally, the reference management will be presented to help organising the information gathered from these readings.

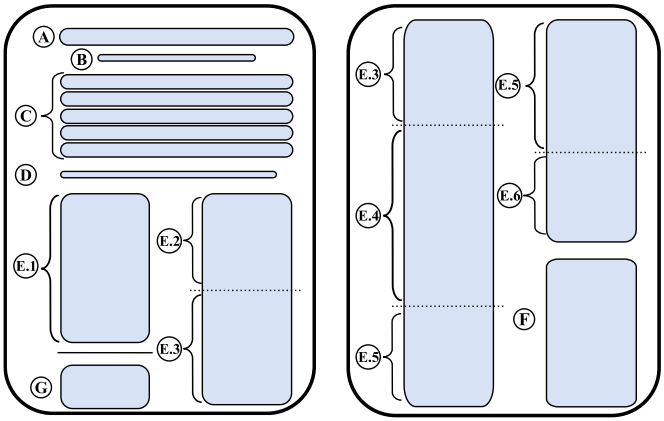
Identify the structure of the scientific work

In this context, the term “work” may refer to a Ph.D. thesis, an academic article,[99] or a research report. Although these three types of work differ in size, purpose, and the process of creation, they share a key similarity: adhering strictly to the scientific method results in a similar structure across all of them.

Figure 5-1 illustrates the structure of an academic article. This section focuses solely on presenting the structure of articles, which are the most common

[99] Academic articles can be divided into four types, most notably: conference articles and journal articles. A conference article is typically around 10 pages long and presents new research findings to the scientific community attending a conference focused on the relevant field of study. In contrast, a journal article is a more substantial piece of research, generally about 20 pages in length, though it can be longer. Journal articles are considered more credible as they undergo a solid peer review process. Further details on this topic are provided in Chapter 8.

type encountered when searching through scientific literature.[100]



a) Page I *b) Page II*

Figure 5-1. Structure of an academic article of two pages

An academic article typically includes the following components:

A. **Title**, it is usually one or two lines long, containing key terms or topics covered in the

[100] The structure of a Ph.D. thesis and a research report differ slightly, particularly in terms of length. However, they generally contain similar sections to those found in academic articles. Additionally, a Ph.D. thesis may include special sections, such as appendices, which are typically not present in shorter works like journal articles, which are usually 10 to 20 pages long. For further details, refer to Chapter 8.

article. It is typically centred at the top of the first page.

B. **Author(s) Information**, This includes the names of the authors, their institutions, and email addresses. Occasionally, some authors may use pseudonyms instead of their real names.[101]

C. **Abstract**, a brief paragraph at the start of the article summarising the entire work. It often mirrors the structure of the article, with one or two sentences summarising each section.

D. **Keywords**, typically, four to five words that define the article's main topics. Not all articles include keywords, as some journals consider

[101] The author's name can pose a significant challenge, as there are often multiple ways or styles of writing it. This can be critical when determining if a particular work is attributed to the correct individual. A robust authority control system, such as the Virtual International Authority File (VIAF), accessible at https://viaf.org, and the International Standard Name Identifier (ISNI), available at https://isni.org, provides a solution by assigning numerical identifiers to individuals instead of relying solely on names.

them subjective and may choose to exclude them.[102]

E. **Body**, the main content of the article, which may be presented in one or two columns depending on the journal's formatting style. The body generally follows the steps of the scientific method, as outlined in the previous chapter, and includes:

    1. A general introduction providing the context.
    2. A brief description of the research problem.
    3. An overview of the research method used to achieve the results.

[102] In some cases, a conflict of interest declaration may also appear as footnote, such as (G) in Figure 5-1. This is where the author discloses any personal or financial interests that could potentially influence the objectivity of the research. Acknowledgements, which is a short section following the conclusion where the author expresses gratitude to those who contributed to the research, might appear there or at the end of the body section.

4. The results, often presented with tables and figures.
5. An analysis explaining the significance of the results and how they compare to expected outcomes.
6. A conclusion summarising the findings and suggesting future research directions.

F. **References**: A numbered list of all sources cited in the article. The number of references can vary greatly depending on the type of article, with some containing more than 100 references, particularly in literature reviews or surveys.[103]

[103] A survey is a type of journal article that summarises the development of a specific technology, tracing its progress from the initial mention of the problem to the current advancements at the time the survey was conducted. Surveys usually focus on technical details, often outlining the history of discoveries related to a particular topic. A survey is not a literature review, which is another type of academic article. A literature review presents all relevant works on the subject, offering comparisons between different studies and highlighting their strengths and weaknesses, see Chapter 8 for more details.

Selective reading algorithm

When investigating a specific problem, it is common to encounter hundreds of works related to the subject. However, it is unrealistic for a researcher to read all these works due to their sheer volume and the time constraints.

Therefore, the researcher must focus on selecting only those works closely related to the research problem. This is called a selective reading, and Figure 5-2 provides a step-by-step algorithm for it:

1. Begin by searching in a specialised search engine, such as Google Scholar,[104] using keywords relevant to the research problem. This will generate a list of articles, which may range from dozens to hundreds. The more specific the keywords, the narrower the search results.

[104] Available at https://scholar.google.com/.

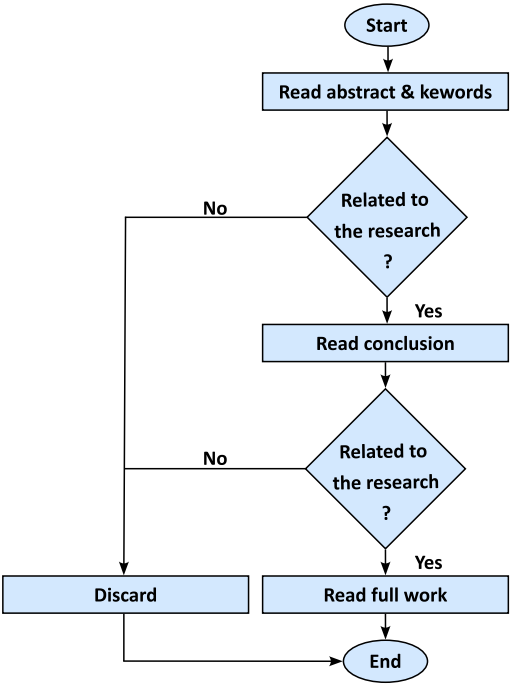


Figure 5-2. Selective reading algorithm

2. Read the abstracts and keywords of the articles found in Step 1.
    a. If an article aligns with the research topic, move to the next step.
    b. If not, discard the article, end.

3. Read the conclusion.
    a. If the conclusion presents findings relevant to the research problem, proceed to the next step.
    b. If not, discard the article, end.
4. Read the entire article, end.

Throughout the process, the list of keywords used at the beginning should be refined based on new findings. The goal is to narrow the scope of the research as much as possible, which is crucial when defining the research problem.

It is also helpful to search for other works by the same author. If an article proves to be valuable, it is likely that the author has published additional works on the same topic. These other works may offer further useful insights and findings.

Reference management

Effective organisation is essential for successful research. This applies not only to following the steps

of the research method but also to managing the data collected throughout the process.

Even with selective reading, the amount of data gathered from references can be overwhelming. To properly define a research problem, around fifty articles are typically required, and this number can grow fast based on the depth of the research. Thus, relying on memory alone is insufficient.

Additionally, researchers should avoid repeating the same search. For instance, if it takes 30 minutes to find the definition of a specific term, that information should be recorded so that the definition can be retrieved later without repeating the same search.

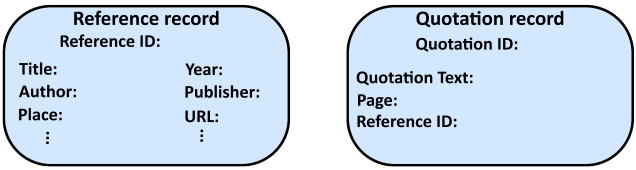
Since the 2000s, reference management has been fully automated through software like Mendeley.[105]

[105] It is a proprietary reference management software, developed by Paul Foeckler, Victor Henning, and Jan Reichelt in 2008, and is currently maintained by Elsevier, see https://www.mendeley.com/. Other examples include BibDesk, available at https://bibdesk.sourceforge.io, and Papers, accessible at https://papersapp.com.

The key is to understand how these systems operate. Once this is clear, using any reference management software becomes straightforward. This section focuses solely on storing data gathered from references.

The data is stored in a database in the form of tables. Homogeneous data is stored in the same table. For example, one table will contain references, and another will store quotations.

Each individual entry in these tables is known as a record, which can be visualised like Post-it notes (Figure 5-3). Entries from different tables can be linked, making the database relational.



a) Reference record *b) Quotation record*

Figure 5-3. Comparison between reference and quotation records

A reference record is used to store all relevant details about a specific scientific source, such as a book or

journal article. This information can include, but is not limited to: title, author, publication year, publisher, and identifiers (e.g., ISBN)[106]. Each reference record must also have its own unique ID.

The second type of record is for storing quotations. This includes the quoted text from the source, the reference ID, and the page number where the quote was found. The reference ID links to the reference record of the source. Each quotation record must also have its own unique ID, providing numeric reference to the quotation card.

In this setup, reference records are grouped and stored in the Reference table, while quotation records are stored in the Quotation table. Relationships are then created between the records in these two tables. It is important to note that this is a deliberately simplified structure. In practice, authors and publishers would have their own

[106] The International Standard Book Number (ISBN), a 13-digit unique identifier assigned to specific editions of books.

separate tables, leading to a larger and more complex database.

For example, Figure (5-3) illustrates how records are related when storing the definition of science discussed earlier in Chapter 3:

- The reference record has the ID R15, where “R” represents reference. This record also contains details about the book, such as the title, author, and ISBN. It may also include additional information like the type of work, in this case: a book and the publisher’s name.
- The quotation record is labelled Q3, with “Q” representing quotation. The record contains the quoted text and the page number where the quotation was found. It also includes the reference ID: R15, which links back to the reference record for the book where the quotation was sourced.

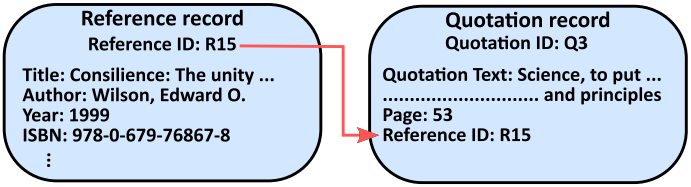


Figure 5-4. Example of reference management

Searching for a research problem

Researchers can identify research problems by observing the physical world around them. Significant problems often arise from keen observation.

An example of research problem defined by observation is the spaghetti stick challenge, proposed by Richard Feynman[107] While cooking in his kitchen, Feynman noticed that it was almost impossible to break a dry spaghetti noodle into just two pieces. This seemingly simple puzzle remained unsolved

[107] Richard Phillips Feynman (1918–1988), an American theoretical physicist who won the Noble Prize in Physics in 1965. He is best known for his contributions to the Manhattan Project, which developed the first atomic bomb, and for his pioneering work in quantum mechanics.

until 2005, demonstrating the value of sharp observational skills in research.[108]

In addition to observation, there are several ways that can help in identifying a research problem:

1. Most companies or enterprises have research and development teams. A useful approach is to email them, inquiring about specific problems they are addressing and whether they have explored potential solutions. It is also appreciable to propose initial ideas and offer assistance.
2. Contacting public or private research institutions, especially those focused on solving the problem of interest. They may be seeking researchers to further investigate the issue.

[108] The solution was published in an article titled: "Fragmentation of Rods by Cascading Cracks: Why Spaghetti Does Not Break in Half", see [ARE15] for details.

3. Reaching out to other researchers or experts working in the same field asking questions about their initial findings. The authors' contact details are usually available at the top of their articles, as discussed earlier. Additionally, looking for open questions in the conclusions of the articles is another possible way.
4. Attending conferences related to the problem is a valuable opportunity to meet and discuss with other researchers working in the field. If attending is not possible, reviewing the conference proceedings, which document the ideas discussed during the event, can be equally helpful.

Three out of the four approaches mentioned above involve sending a message or email to communicate. Therefore, another essential soft skill is the ability to write formal and well-structured messages.

An effective message should include the following elements:

- A brief self-introduction at the beginning, with links to the researcher's previous work, if available.
- A concise and well-described explanation of the message's purpose.
- Contact information, such as phone number, and postal address.

Regardless of the starting point, the researcher should proceed by using a general research search engine, like Google Scholar[109], or domain-specific search engines. At this early stage, the research problem should be described using three or four key terms, then searched, followed by selective reading of the results.

At this point, it is crucial to use both selective reading and proper reference management. Selective reading

[109] Available at https://scholar.google.com/.

ensures that only the most relevant materials are reviewed, while reference management helps to organise the knowledge gathered efficiently.

There are two components of scientific work that guide the process at this stage:

1. **References**, by expanding the scope of the research. When initiating a study, it is important for the researcher to begin broadly.
2. **Keywords**, by narrowing the focus of the research, serving the opposite purpose of references. It is logical that the research domain is broad, and one of the key objectives is to scope down the research as much as possible.

The diamond model illustrated in Figure 5-5 visually represents this process.

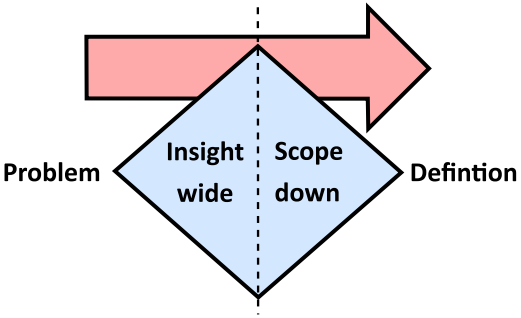


Figure 5-5. Diamond model for defining problems

When a researcher begins to seek something new, such as a specific problem or concept, the initial approach should be broad. Once sufficient information has been gathered and the problem is well-understood, the goal is to narrow the focus and concentrate on defining the problem itself.

Unfortunately, there is no definitive moment for this transition, it is entirely based on practical experience. The more a researcher engages with the diamond model, the more familiar he becomes with it, gaining insight into when to stop broadening their research and when to refine it.

Defining the research problem

Defining a research problem is a lengthy process and cannot be achieved in a short period of time. Quick and methods with shortcuts are often unreliable and can lead to mistakes in identifying the problem. Rushed research usually results in finding problems in defined problem.

The more a researcher reads about the problem, the deeper his understanding becomes, which in turn improves the ability to accurately describe and define the problem.

A research problem can be well-defined in two keyways:

1. **By context,** it involves clarifying what aspects are relevant to the problem and what should be excluded, helping to set boundaries by identifying what to address and what not to.
2. **By syntax,** focusing on defining the problem itself, without considering its broader

context. There are three approaches to achieve this:

I. **Using description,** the simplest method, where the problem is directly described with short sentences.

II. **Using questions,** this method involves formulating specific questions that the research will aim to answer. It is more challenging than description for two reasons:

- The questions must be well-defined. Otherwise, they can mislead the research away from the core problem.
- The questions must be organised logically into groups or categories, so they form coherent units, with each addressing a specific aspect of the problem.

III. **Using hypotheses,** this is the most complex approach. According to the scientific method discussed in Chapter 4, particularly in Step 8 (retesting), hypotheses can be formulated when the researcher starts based on others' work. Implicitly, this means the researcher has already some hypothesis to test using theories proposed by the other researchers.

The following subsections will explore both keyways of defining a research problem, providing detailed examples for each.

Defining by context

When defining a problem by context, the key is to distinguish the problem from its surrounding elements. This involves identifying what is part of the problem and what is not. Defining by context does not require addressing every aspect of the problem,

but the more aspects covered, the less ambiguous the problem becomes to tackle.

Time aspect

The first aspect to consider is time. The researcher can select a specific time period to focus the problem, which is particularly useful when the time span is large and includes significant technological changes. The aim is to narrow the timeframe to ensure that the data collected is comparable.

For example, when studying how travel affects people's lives, it is impossible to cover all human history in the same way. In the Middle Ages, it was common for people to be born, live, and die in the same town or village, as travel was difficult and dangerous. This cannot be compared to travel in the 2010s, where people can travel to the other side of the world in less than a day. A practical method would be to divide human history into periods based on the evolution of travel technology. The researcher

could then choose two periods, apply a research method, and compare the results.

Another example is the data sources on the Internet. Before mid-2000s, when social media platforms were not yet widespread, the nature of data available online was vastly different. A study of internet data would consider the rise of social networks as a key turning point. Before this, most data were in text form forums and blogs, while after the social media revolution, data became more personal and included more multimedia.

Location aspect

The second aspect to consider is the location or setting where the problem occurs. This could involve restricting the problem to a specific geographical area or focusing on a particular group of people.

An excellent example is the study of gender gaps,[110] where defining the problem's scope by location can be helpful. For instance, when examining the gender gap on English Wikipedia,[111] the problem has already been limited in two ways:

1. The focus is restricted to Wikipedia, excluding data from other parts of the Internet.
2. The study is further narrowed to English Wikipedia, meaning it only involves English-speaking contributors.

Sources aspect

The third aspect can be a valuable tool when conducting a comparative study. The problem can be defined by focusing on specific sources.

[110] A gender gap refers to the unequal differences between men and women in various areas of society, such as culture and the economy.

[111] A 2021 study analysing the content of English Wikipedia in 2017 revealed that only 17% of the biographies published in the encyclopaedia were about women [ARE15].

For instance, consider a study on colonialism[112] from the native perspective. In this case, the research framework is already established, limiting the study's boundaries to a specific source: the native people. Since the study is not comparative, the researcher should focus solely on sources created by native individuals.

In such studies, concerns may arise regarding bias and objectivity. The researcher must clarify why only these particular sources were selected and acknowledge the existence of other perspectives that are beyond the scope of the current research.

Using the gender gap in English Wikipedia as an example again. Sources, in this case, can be limited to English-language sources, non-English sources, or any specific language. Whatever the choice is, the researcher needs to:

[112] The Stanford Encyclopaedia of Philosophy defines colonialism as: "The practice of domination, which involves the subjugation of one people by another". See [WEB07] for details.

- Provide a detailed justification for the choice, demonstrating that it is deliberate and not random.
- Ensure there are sufficient sources related to the chosen language, so that the research is not negatively impacted by the selection.

Define by syntax

Defining a problem by syntax involves focusing on the problem itself, rather than what separates it from its surroundings. As previously discussed, there are three methods for defining by syntax: through questions, description, or hypotheses.

Regardless of the method chosen, there must always be a central or core idea that all the information revolves around. This could be a key question, if defining by questions, a main statement, if using description, or a core hypothesis, if using hypotheses.

Defining by syntax implicitly states that research cannot begin from nothing. It is advisable that the core idea builds upon existing work in the field. This does not mean that a researcher cannot challenge something they believe is invalid.[113] Rather, it acknowledges that each research domain follows a general direction shaped by ongoing work. This direction is not fixed, it evolves slowly over time. A single piece of research cannot shift the entire course of a field due to the vastness of the scientific community. However, individual studies can contribute small changes, which, over time, may influence the broader direction.

Using description and questions

Defining the problem by descriptions is similar to defining by questions, with a major difference: The

[113] It is strongly advised for early-career researchers to avoid challenging scientific consensus unless there is substantial evidence, supported by experts in the field. While it is not impossible to demonstrate that the scientific community has accepted invalid ideas about something, it is uncommon due to the inherently cautious and skeptical nature of science.

syntax in the first way is a full sentence, while in the second it is a question. Table 5-1 shows how to define the problem in the gender gap using description and questions.

Table 5-1. Defining the gender gap research problem through description and questions

Defining by description	Defining by questions
In this study, the researcher aims to explore the following aspects: a. The potential relationship between gender and the number of biographies on English Wikipedia. b. The different types of gender gaps within the context of English Wikipedia, such as the gap in biographies by subject area. c. The similarities and differences between various types of gender gaps. d. The characteristics of the gender gap, with a particular focus on the gap related to biographies of women.	In this study, the researcher will seek to answer the following questions: a. Is there a relationship between gender and the number of biographies on English Wikipedia? b. What types of gender gaps exist, and is there a connection between the type of gap and the context in English Wikipedia? c. What are the differences and similarities between the various gender gaps? d. Does the issue have specific characteristics, or does it follow a consistent pattern whenever it is identified?

Using hypotheses

Using description and questions is generally more suitable for descriptive research methods, whereas hypotheses are better suited to inductive research methods. Defining a research problem through a hypothesis is the most complex method, as it demands a thorough understanding of the research field.

When defining a problem with a hypothesis, the researcher focuses on identifying relationships between two or more variables and investigates how they influence each other. This relationship must be articulated as a statement, which will then be tested in the course of the research.

There are various types of relationships between variables. Below is a non-exhaustive list of some commonly used relationships:

- **Causal relationship**: In its simplest form, this involves two variables, A and B. Variable A

causes Variable B to exist or prevents it from existing.

- **Direct proportional relationship**: When Variable A increases, Variable B also increases, and similarly, when Variable A decreases, Variable B decreases.
- **Inverse proportional relationship**: When Variable A increases, Variable B decreases, and conversely, when Variable A decreases, Variable B increases.

When formulating a hypothesis, the following guidelines should be kept in mind:

- A hypothesis should a stand-alone statement based on either simple or complex scientific facts. If the hypothesis is too broad, it should be broken down into smaller, testable hypotheses, with each tested individually.
- The hypothesis must be expressed in the present tense, as it represents a claim to be tested in the next step of research. This differs

from defining a problem using descriptions or questions, which can be written in past, present, or future tenses.

- A hypothesis should offer detailed, definitive options, such as whether something exists or does not exist. It should specify whether a relationship between variables is present or absent. While not limited to two variables, a hypothesis must cover all possible outcomes with a finite set of options.
- A hypothesis must have a practical implementation that can be tested. In Part I, it was noted that a hypothesis is closely tied to physical reality, whereas theories are more abstract. Therefore, when developing a hypothesis that links two or more variables, the researcher must ensure that these variables can be observed and measured in the real world, allowing the hypothesis to be tested and not remain theoretical.

- A solid hypothesis should be able to predict future outcomes based on current and previous data.[114]
- A hypothesis needs also to be simple and understandable. While research can include multiple hypotheses, it is generally recommended to focus on a single hypothesis per study to direct efforts effectively. If several hypotheses are necessary, a suggested approach is to have one central hypothesis as the foundation, supported by smaller, related hypotheses.

The first example focuses on a hypothesis[115] involving three variables in direct proportion, using the gender gap in English Wikipedia as the problem to be studied.

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[114] This is not astrology or fortune-telling. For more on this topic, refer to Chapter 2.

[115] The two hypotheses presented as examples are intentionally oversimplified for the sake of clarity. They can be critiqued or further refined.

The first variable is the total number of articles in English Wikipedia, while the second and third variables are the number of biographies of men and women. These variables will then be examined over time. The data will include the number of articles each month from January 2012 to January 2022 (Table 5-2).

Table 5-2. Time-based table for variables value

Month (yr)	# bio ♂	# bio ♀	Ratio
Jan (12)			
Feb (12)			
Mar (12)			
⋮	⋮	⋮	⋮
Jan (22)			

The hypothesis states that the ratio between the number of women's biographies and men's biographies remains constant. In other words, if you divide the number of women’s biographies by the number of men’s biographies, the result will remain the same, regardless of how much the English Wikipedia grows.

This hypothesis can be expressed as:

The total number of biographies is directly proportional to the number of women's biographies, as the size of English Wikipedia increases from January 2012 to January 2022, measured on a monthly basis

This is a hypothesis, a claim that will be tested later. Even if it turns out to be invalid, it is still important to understand why and explore any possible patterns or hidden relationships between variables.

The second example presents a hypothesis suggesting a causal relationship between two variables. It is based on the idea that the gender gap may vary depending on age. For certain age groups, there might be no gap at all, while for others, the gap could significantly reduce.

To formulate the hypothesis, only two variables will be used: the number of biographies of women and the number of biographies of men. The collected data

will be categorised into five groups as follows (Table 5-3):

1. Individuals under 18 years old.
2. Individuals aged 18 to 39.
3. Individuals aged 40 to 59.
4. Individuals aged 60 and above.
5. Deceased individuals.

Table 5-3. Age-based table for variables value

Age	# bio ♂	# bio ♀	Ratio
Up to 18			
18-40			
40-60			
+60			
Dead			

The number of biographies will then be analysed by age, and the gap will be assessed as a function of age.

The hypothesis can be stated as follows:

The gender gap in the number of biographies on English Wikipedia is influenced by individuals' age

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In this example, the relationship is causal. A change in the value of one variable will lead to a change in the value of the other variable. In this context, this means that either the age of individuals contributes to the gap, or it does not.

Once again, this is a claim to be tested. It may be valid or invalid. If it is found to be invalid, this does not conclude the research. The researcher must seek to understand why the hypothesis was invalid and propose alternative explanations or solutions.

Research problem properties

In this section, the research problem will be examined as a subject. Four key aspects of research problems will be addressed:

1. The status of the problem, this refers to the current state of knowledge and achievements related to the problem on a global scale.

2. The size of the problem, it refers to what needs to be considered within the problem boundary, ensuring it is well-defined.
3. The availability of tools and resources, this addresses the tools and sources necessary for studying the problem.
4. The studyability of the problem, this involves determining whether the problem can be effectively studied.

The subsequent sections of this chapter will provide a detailed discussion of each of these aspects.

The status of the problem

This property examines the current state of the problem at the time of conducting the study. As discussed in Part I, the creation of scientific knowledge is an ongoing process, so it is likely that other researchers have already considered and attempted to address the problem. Thus, the researcher must investigate first recent developments related to the research problem.

There are four possible outcomes:

1. **The problem is resolved**: A solution already exists, and the researcher can verify it independently. It is not advisable to attempt solving the problem again. However, the researcher has three potential paths:
    a. Define a new problem based on the recent findings.
    b. Optimise the solution by improving the efficiency or methods used to achieve the same results.
    c. Move on and explore a different research problem.
2. **Ongoing research**: If other researchers are actively working on the problem but has not yet solved it, the researcher should ideally contact them to request a summary of their findings. However, the response might be negative or non-existent. Still, if the researcher receives a positive reply, it can significantly refine the problem. It is

also beneficial to monitor the publications of those researchers working on the problem, as these might provide valuable insights.

3. **Unsolvable with current knowledge**: In cases where the problem has been proven unsolvable with current tools or knowledge,[116] the researcher should verify this claim independently. If confirmed, it is advisable to shift focus to a different problem.
4. **Unaddressed problem**: If the problem remains open, with no existing research, the researcher has the opportunity to tackle it using the scientific method.

Size of the problem

The researcher must select a problem that is feasible within his current capacity. Therefore, it is essential to define the problem in detail, taking into account

[116] It is essential to check the publication date in such cases, as there may have been significant breakthroughs or advancements in the research field since the article was published.

the time available and the duration required to apply the scientific method. Estimating this can be complex for early-career researchers, so it is advisable to seek guidance from experienced researchers in the field. Based on their experience, they can provide a more accurate estimate. This also highlights the importance of communication among researchers when applying the scientific method.

The researcher must also consider the cost involved. For example, funds may be needed to purchase materials for experiments, and if the budget is exceeded, it could directly affect the research. There may also be a need to travel for testing, accessing specific resources, or attending scientific conferences. These factors should all be taken into account when defining the research problem.

Availability of tools and sources

It is crucial for the researcher to be aware of the technological limitations within the field of the research problem. A hypothesis might require

specific tools or resources, such as computational power for testing, and these tools may not yet be available.

Another scenario is that while the required technology exists, it may not be accessible due to restrictions. For instance, certain advanced technologies may be classified for national security reasons in various countries, limiting public access. This is a common issue concerning sources and documents. Some materials, like ancient manuscripts, are held in private collections. Therefore, while they exist, they are not accessible for research. Additionally, certain government-generated documents, such as sensitive demographic statistics, may be classified and unavailable for public access. In many instances, there may be laws that

restrict the collection of such data for research purposes.[117]

In this context, it is also important to distinguish between what is free and what is open, as this can significantly affect the cost of the study. “Free” indicates that the researcher can access tools or sources without any costs. Conversely, some sources and tools may be classified as open, meaning they are publicly accessible but require a fee for access or use.

[117] Laws regarding data collection and processing vary depending on the country in which the study is conducted. For instance, in France, it is illegal to process personal data that reveals an individual’s alleged racial or ethnic origin, political opinions, religious or philosophical beliefs, or trade union membership, as well as to handle genetic or biometric data intended for the unique identification of a person (Article 6 of the Law of 6 January 1978). In Egypt, collecting or processing sensitive data requires prior approval from the Data Protection Centre. Sensitive data in this context includes psychological, mental, physical, or genetic information, biometric or financial data, religious beliefs, political views, or criminal records (Article 1 of Law No. 151 of 2020).

Studyability of the problem

This refers to the feasibility of the research being conducted. Several aspects must be considered in this context:

1. **Is it safe to conduct the study?** This can be understood in two different ways:
    a. **Natural risks**: For instance, if the research is taking place on an isolated island, atop a volcano, or deep in the ocean, ensuring safety is unquestionable.
    b. **Human factors**: There may be individuals or groups who could be adversely affected by the study and may attempt to obstruct it. In social sciences, for example, a government may seek to conceal certain information, a criminal organisation may be active in the area, or a political or religious group might be concerned about

the potential implications of the study's findings.[118]

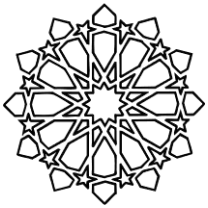
2. In certain cases, knowledge of specific languages is essential, without this knowledge, the problem cannot be addressed effectively. For instance, if most of the sources relevant to the research are written in a particular language, the researcher must be proficient in that language. For example, nearly all texts related to Islamic studies are composed in Arabic, making it a pre-request for researchers in this field.

   In other cases, the language may be spoken but lacks a written system. Many anthropologists who have lived among and studied indigenous populations have had to learn their native languages. Translation is

[118] A recent example involves the threats faced by scientists researching climate change. A study conducted in 2022 revealed that these scientists experience persistent online harassment related to their work, which includes death threats, trolling, and sexual abuse, see [ARE17] for more details.

often inadequate, as some nuances of meaning are invariably lost in the process. In anthropology, this aspect is vital and must not be overlooked.

3. Researchers must always maintain an objective perspective concerning the problem under investigation. If a researcher holds strong personal opinions that could interfere with their reasoning and judgment, the problem may not be appropriate for them to study. This is a significant concern in the social sciences, including fields such as politics, economics, and religion



On the sources

Introduction

Science is an ongoing process, and sources serve as valuable tools to demonstrate this continuity. In research, scientists build upon existing knowledge. Typically, they begin with sources produced by other scientists, and the findings of their research then become sources in the future.

In Chapter 4, when discussing the scientific method, the state-of-the-art was defined as the forefront of human understanding. It is the foundation that supports research, as scientists seek references to ensure they start new research on solid ground.

In the first part of this chapter, the state-of-the-art will be introduced, outlining its objectives and various types. Detailed steps will be provided on how to create it, with particular emphasis on what to include and what to avoid. The second part will concentrate on the references used in research, discussing how to

classify them, their properties, and the different types available.

The state-of-the-art

In Chapter 4, the state-of-the-art was introduced as a step in the scientific method. In nearly all cases, once the problem is defined, conducting the state-of-the-art follows as the next step.

During this step, the researcher must explore further to enhance his understanding of the problem. The research problem will be affected as a result of having solid knowledge.

The term “state-of-the-art” refers to:

The cutting or leading edge of the human knowledge

This definition implies that the researcher must understand the current knowledge surrounding the identified research problem. It is also important to

determine who is actively working on the problem, if anyone, and what their efforts involve. This helps to prevent the duplication of work that has already been completed.

Chapter 4 also emphasised that the research problem is likely rooted in the work of other researchers. Therefore, conducting a thorough state-of-the-art involves searching for these works, assessing their reliability, and correctly incorporating them into the existing state-of-the-art.

At this stage, it is crucial to understand that the state-of-the-art is not merely a random collection of articles and studies related to the research problem. Instead, the gathered works must be organised, analysed, and presented as a coherent summary.

By the conclusion of the state-of-the-art, the researcher is expected to have gained a comprehensive understanding of the defined problem. This acquired knowledge should be utilised to improve the description of the research problem.

The state-of-the-art is the stage where researchers review the works of others, rather than in the later steps of the research process. If, during the later stages, a researcher discovers an article that significantly contributes to the solution but was overlooked, it could invalidate the entire research. The same applies if the researcher learns, after a year of working that someone resolved the problem he is handling, for example, two years earlier.

In simple terms, the researcher must take time to thoroughly conduct the state-of-the-art, ensuring that all aspects of the problem are addressed.

Next, there are five main sections to cover the state-of-the-art in detail: the objectives of the state-of-the-art, its types, what to include and what to avoid, and finally, how to conduct a state-of-the-art.

Objectives

This section aims to address two key questions: Why is the state-of-the-art conducted? And what do researchers hope to achieve when it is done correctly?

There are six aspects that need to be covered to help answer these two questions, The state-of-the-are is performed to:

1. **Confirming the problem is still unresolved**: The first objective is to verify that the research problem remains open, with no existing solution proposed. If the problem persists, the next step is to identify who is currently working on it. If the topic is popular within the research field, it is likely that others are investigating it. Understanding their work helps to avoid unnecessary repetition.
2. **Placing the research problem within the broader context of knowledge**: It is essential to determine how the research problem fits

into the wider scope of human knowledge, especially within the specific research domain. Reviewing the most recent studies in the field is an effective way to achieve this. Open questions often represent the boundaries of current knowledge, and by identifying these gaps and comparing them with the research problem at hand, the researcher can position their work accurately.

3. **Gaining a deeper understanding of the problem's context**: Thoroughly reviewing scientific works related to the research problem often reveals paths that have already been explored and proven ineffective. For instance, a hypothesis that has been tested and invalidated can help avoid unnecessary efforts, allowing the researcher to narrow the research design.
4. **Identifying alternative research methods**: By examining how other researchers have

tackled similar problems, the researcher can gain insights into the methods they employed, the reasons behind their choices, and whether these methods could be reused or improved. This can significantly reduce time and effort. The state-of-the-art is not about gathering information from scientific works, but also about exploring research methods and strategies that can be reused to strengthen the upcoming research.

5. **Helping the researcher discover a wealth of sources related to the research problem**: Each scientific work includes a reference section where the author cites other works used in their research. It is highly recommended to explore the reference sections of relevant works to find additional sources related to the research problem.
6. **Creating the timeline of the research problem:** Exploring the reference sections of

others' works is like taking a journey through time, as the collection of cited articles can be organised to form a timeline. This timeline starts with the earliest instance when the research problem was first raised and continues to the most recent contributions showing the current progress towards its resolution. By creating such a timeline, researchers gain a clear chronological understanding of the problem, allowing them to predict potential future developments or the next major step in addressing the issue.

Types

Depending on its purpose, the state-of-the-art can be categorised into two types:

- Stand-alone state-of-the-art, also known as a survey. It is an academic journal article dedicated to presenting the current advancements related to a specific research problem.

- Integrated state-of-the-art, which is included as part of a larger research work, such as a research report or a Ph.D. thesis, and is typically found in the first or second chapter.

Table 6-1 provides a comparison of these two types based on the following four criteria. They are:

Table 6-1. Stand-alone and integrated state-of-the-arts comparison

	Stand-alone state-of-the-art	**Integrated state-of-the-art**
Expected output	Stand-alone complete work	Part of other research work
Contribution of the research	• Limited, no new results • Might include analysis of what are the open questions regarding the research problem	The base over which the original research will be built in later step.
Publication type	Academic article (Survey)	Part of research report or Ph.D. thesis
Utility	Others save time and effort when studying the problem	Reform the research problem on which the research will try to answer

1. **Expected output**: This refers to the result produced once the state-of-the-art is completed.
2. **Contribution of the research:** This indicates the added value of the work. As discussed in Chapters 1 and 2, each scientific work should contribute new knowledge.
3. **Publication type**: This refers to the final form of the publication that will include the state-of-the-art.
4. **Utility**: This explains how other researchers can benefit from the state-of-the-art.

There is also a rare third scenario where no previous studies are available on the research problem, though this is an uncommon occurrence.

The first step the researcher must take in such a situation is to thoroughly verify the absence of previous studies, double-checking multiple times before accepting this conclusion. While it is not impossible, it is exceptionally rare for a researcher to

address a problem for the first time in human history. As discussed in Chapter 1, human knowledge expands gradually, and it is unusual to encounter something entirely new that cannot be linked to the existing understanding of the world.

However, “very rare” does not mean impossible. For instance, in 1736, Leonhard Euler[119] published a paper in the Commentaries of the Petropolitan Imperial Academy of Sciences[120] addressing a unique

[119] Leonhard Euler (1707–1783), a mathematician, physicist, and engineer, born in Basel and passed away in Saint Petersburg. Throughout his distinguished career, Euler made several notable contributions to mathematics and science. He is recognised for defining the constant *e*, known as Euler's number, which is the base of the natural logarithm. He also introduced the use of the Greek letter π to represent the ratio of a circle's circumference to its diameter and the letter *i* to symbolise the imaginary unit in complex numbers.

[120] The journal was written in Latin, with the original title: “Commentarii Academiae Scientiarum Imperialis Petropolitanae”. The title of Euler's original article was: “Solutio problematis ad geometriam situs pertinentis”, which translates literally as “Solution of problems related to the geometry of position”. Refer to [ARL01] for the original article.

problem found in Königsberg[121], Prussia. The city was divided by the Pregel River, with two islands connected to the mainland by seven bridges. The challenge was to determine whether it was possible to walk through the city, crossing each bridge only once (Figure 6-1).

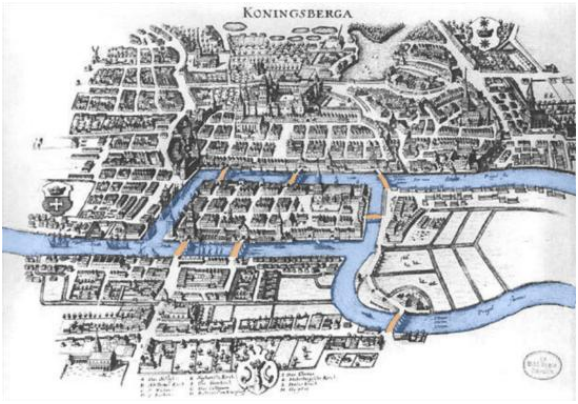


Figure 6-1. The problem of the seven bridges of Königsberg[122]

When the problem was first introduced, there were no previous studies addressing anything similar. Although Euler concluded in his article that the

[121] Now known as Kaliningrad (Russian: Калининград), it is the capital of Kaliningrad Oblast in present-day Russia.
[122] This is a modified version of the original illustration created by Matthäus Merian the Elder (1593 - 1650).

problem was unsolvable and that it was impossible to cross all seven bridges in a single walk, this work is now recognised by historians of mathematics as the beginning of a new branch of mathematics known as graph theory.

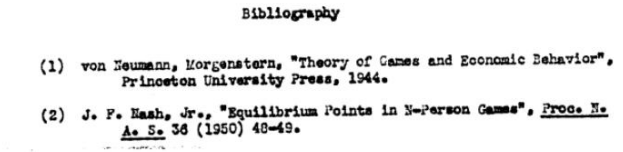
A more recent example is John Nash[123] and the development of game theory[124]. Nash, a Ph.D. student at the time, created a new field that bridges Economics and Mathematics, now called game theory. It provides a framework for understanding human behaviour, not only in economics but also in real-life situations. Nash was the first non-economist

[123] John Forbes Nash, Jr. (1928–2015), an American mathematician best known for his significant contributions to game theory, including concepts named after him such as Nash equilibrium, Nash functions, and the Nash bargaining game.

[124] Outside academic circles, Nash is widely recognised for the film “A Beautiful Mind”, which is based on his life story. The film won the Academy Award for Best Picture in 2001.

to win the Nobel Prize in Economics in 1994 for his groundbreaking contributions to this field.[125]

When Nash wrote his thesis[126], he was the first person to explore this subject, so there were no prior studies or references available for him to use. A typical Ph.D. thesis often includes 100 to 200 references, and in some cases even more. It is uncommon for a thesis to be approved with fewer references than this. However, Nash's thesis contained only two references (Figure 6-2).



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(1) von Neumann, Morgenstern, "Theory of Games and Economic Behavior", Princeton University Press, 1944.

(2) J. F. Nash, Jr., "Equilibrium Points in N-Person Games", Proc. N. A. S. 36 (1950) 48-49.

Figure 6-2. A screenshot of Nash bibliography section in his these

[125] Nash shared the Nobel Prize with John Harsanyi (1920–2000) and Reinhard Selten (1930–2016). The Nobel Prize committee noted their achievement as being “for their pioneering analysis of equilibria in the theory of non-cooperative games”.[WEB08]

[126] Nash completed his thesis in May 1950 at Princeton University, titled “Non-Cooperative Games”. The thesis consists of 26 pages and includes only two references. [THS01]

Conducting a state-of-the-Art

Doing a state-of-the-art on the studied problem is a major step toward advancing in the research. This section outlines how to conduct it effectively, including what to include, what to avoid, and key considerations.

There are four main steps to follow in order to carry out a state-of-the-art:

1. Collecting relevant studies and scientific works related to the research problem. A general research search engine, such as Google Scholar, serves as a useful starting point.

   Employing selective reading is advisable. As soon as the collecting process begins, there will likely be hundreds of pages to review, with many being irrelevant to the research focus. Therefore, it is highly recommended to implement selective reading to quickly eliminate unrelated content.

It is essential to compile a list of keywords that encompass the main aspects of each selected work. The use of reference management software, as discussed in Chapter 5, is strongly recommended.

2. Defining the outlines of the state-of-the-art. Outlines represent the key themes addressed in the articles, theses, or other scientific works gathered in the previous step. Once a selection of articles closely related to the research problem is collected, the researcher can identify recurring themes through careful reading and analysis. A primary objective is to recognise these patterns and themes.

   An effective state-of-the-art is organised by themes rather than by authors or individual works, and structuring it based on the latter two is a common mistake. However, once the themes have been identified, each can be

examined in relation to the corresponding works.

Another approach, in certain instances, is to analyse each theme according to the authors. In this scenario, there may be a key contributor to the solution or a prominent research institution that has been engaged with the problem for an extended period. The prolonged involvement may lead to the development of a unique research method. Therefore, presenting the works gathered in the state-of-the-art, by authors or research institutions, can be the most effective strategy in these scenarios.

Outlines are not a fixed structure; rather, they are dynamic. As the research progresses, the outlines will become increasingly precise. In many cases, the researcher may need to eliminate some outlines from the list because

they have become too broad as the research problem is refined and specified.

3. Presenting all valuable and reliable perspectives collected regarding the research problem. These various viewpoints contribute to identifying the main currents that address the research issue.
4. Analysing the collected data presented in the previous step. This analysis is the final and most crucial step of the state-of-the-art, where the researcher seeks to explain the differing opinions on the subject under study and how these insights will help build the method to address the research problem.

By the end of the state-of-the-art, the original research problem formulated at the beginning should become too general to continue with. Instead, a new, well-defined research problem will emerge based on the findings from the state-of-the-art.

What to include?

The state-of-the-art is an organised presentation of current human knowledge related to a specific research problem. It does not aim to cover all the knowledge ever produced on the subject, but rather highlights the current boundaries of understanding within the context of the problem.

Given the vastness of human knowledge, the amount of information retrieved when using search engines with keywords can be overwhelming. However, it is unlikely that all the results will directly address the exact research problem. Most of the findings will cover only certain aspects of the problem, which is why it is crucial to narrow down the keyword list to focus on a specific research domain.

For example, when studying the relationship between violence and young people in a given society, using general keywords like “violence” and “youth” in Google Scholar might bring up results related to violence in sports. While these are not

relevant to the research focus, they match the search engine's criteria. There is a need to narrow the research. Therefore, the researcher should specify the research domain by adding more targeted keywords, such as "social" or "society", to better align with the research focus.

Next, the research focus needs to be further narrowed. Each domain contains various fields of interest, and the research problem is likely connected to one or two specific fields. Therefore, scientific works from these relevant fields should be prioritised over other findings.

This means that the researcher must begin by categorising the works according to themes. Priority should be assigned to the theme, not the individual articles. For instance, if the research is on binary logic in computers, the main domain would be mathematics, not physics or geography. However, mathematics itself is a broad field with subfields like algebra and calculus, which may be unrelated to the

research problem. In this case, binary logic falls under set theory (Figure 6-3). Therefore, works related to set theory should be prioritised over those related to calculus, even though both belong to the domain of mathematics.

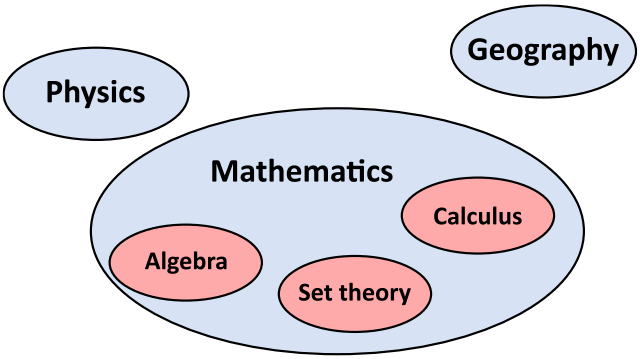

Figure 6-3. Research domains and fields on interests

To achieve that, establishing a system of priorities is essential. This approach assigns a priority level to each category, helping to manage the vast amount of information. Using the previous example, a simple three-point scale can be applied:

- One point: If the subject falls outside the research domain, for instance, in physics or geography.
- Two points: If it is within the general domain but outside the specific fields of interest, such as algebra or calculus within mathematics.
- Three points: If it belongs to the relevant field or fields of interest closely related to the research problem, such as set theory for binary logic.

This example illustrates the concept, but in practice, the system of priorities might be more complex depending on the nature of the research.

What to avoid?

There are several critical errors must avoided when conducting a state-of-the-art. This section will outline these mistakes as a list, its elements:

- The state-of-the-art is not merely a collection of everything the researcher finds on the

research problem. The purpose of the-state-of-the-art is not to list all sources but to identify the key themes related to the research and understand how they are interconnected. Therefore, it is important to summarise each scientific work using a few key terms that reflect its main themes.

This also means that the researcher must classify, sort, and analyse the collected data:

a. **Classify**: It means to group together articles that share common features, such as the year of publication or other relevant categories that serve the research.
b. **Sort**: It refers to the act of arranging the articles within each group, often in chronological order, though other criteria may be used if they benefit the research.

c. **Analyse**: Meaning to draw new insights from the results of classification and sorting, further advancing understanding of the research problem.

- The state-of-the-art is not simply about creating abstracts or summaries of other works related to the research problem. In many cases, while reviewing other studies, the researcher may identify issues in the research methods or inconsistencies in the results. It is important to highlight these concerns, explain how they were detected, and justify why the researcher believe there is a need for improvement or correction.
- The state-of-the-art is not intended to be a bibliography section. Researchers should avoid including detailed bibliographical information, such as publisher names or page numbers, in the state-of-the-art. Such details

belong in the bibliography section at the end of the document. However, there are instances where mentioning the year of publication is necessary, especially when creating a chronological order or timeline. Similarly, the author's surname might be used instead of the full title to reference the work. If an author has produced multiple works that need to be cited, it is helpful to refer to them using the author's surname and the year of publication. If this does not sufficiently distinguish between the works, such as when two articles by the same author were published in the same year, adding details like the publisher, conference, or journal name is a useful approach. This helps avoid confusion while keeping the state-of-the-art focused and organised.

- The state-of-the-art should not be treated as a debate or confrontation with other

researchers. It is essential for the researcher to avoid criticising authors personally and instead focus on evaluating their work. Criticisms should be aimed at the research itself, not the individuals who created it.

It is advisable to review the work multiple times and approach it objectively before making any final conclusions. A good practice is to search for later versions of the work or subsequent publications by the same author(s). It is quite possible that any identified errors have already been corrected by the author. Additionally, it is useful to check if other studies support the same viewpoint or reach similar conclusions. If such studies exist, this does not necessarily invalidate criticism but suggests a need for further verification before finalising any negative assessment.

The references

Basic terminology

In research, the terms “sources” and “references” are often used interchangeably to refer to any form of literary work, typically intended for public access. This broad term encompasses a wide range of materials, from ancient surviving manuscripts to modern-day webpages created in the 21st century.

Publications are the most common type of source, including journal articles, books, research reports, and encyclopaedias. However, sources extend beyond written material to include items like maps, musical recordings, visual media in national archives as well as digital datasets and mailing lists.

Referring to specific information within a source is known as a “citation”.[127] To cite means to provide the

[127] Citation involves paraphrasing, summarising, or rewording a piece of information from a source. This should not be confused with “quotation”, which means presenting the information exactly as it appears in the source, word for word.

exact location of that information within the source, ensuring it can be retrieved without ambiguity. Since sources vary in type, the details required for citation differ. For example, when citing a book, the page number and edition are crucial, whereas citing a musical recording in a national archive requires noting the exact time the information appears, down to minutes and seconds.

Academic articles are the dominant sources in modern research, making it inevitable to understand key citation terms like volume, issue (also called number), and pages. Journals are published periodically, often monthly or biannually, and each publication is called an issue, refer to as “No.” as well. Each issue contains several articles and has its own page numbering system. Multiple issues are grouped together to form a volume (Figure 6-4), which could represent a year’s worth of issues. However, it might also follow a different numbering system. Therefore,

to accurately cite a journal article, volume, issue, and page numbers are necessary.

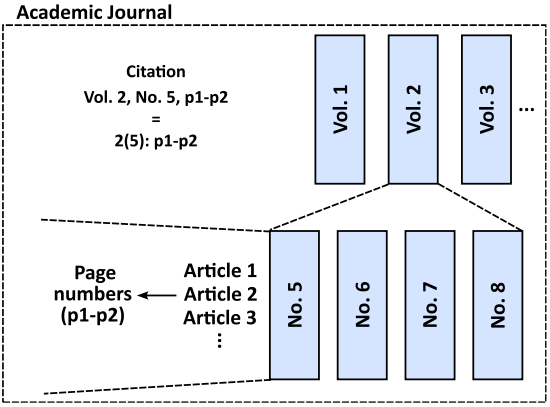

Figure 6-4. Hierarchical structure of an academic journal publication

Books also use the term “volume” to refer to a part of a larger work. If a book exceeds 500 pages, it is likely to be divided into two or more volumes. In such cases, specifying the volume where the information is found is as important as noting the page number.

When a book is republished with updates or corrections, these changes can alter the page numbering from the original edition. Therefore, if multiple editions exist, it is essential to mention which edition was used.

The term “citation style” refers to the specific format and order in which citation details are presented. For example, a citation might start with the author's name, followed by the publication year in parentheses, then the title in quotation marks, and so on.

Examples of citation styles include the Modern Language Association (MLA), the American Psychological Association (APA), and the Chicago Manual of Style (CMOS).[128] Each style has its own detailed manual, often hundreds of pages long, addressing all the nuances and special cases for citations.

No citation style is inherently better than another. However, certain research fields may prefer one style because it highlights information relevant to that domain. Additionally, some academic journals and

[128] Check [BKE15] for MLA, [BKE16] for APA and [BKE17] for CMOS.

publishers may require a specific citation style for editorial consistency. If no particular style is mandated, it is advisable to use one style consistently throughout the entire work to maintain coherence.

Authority control

Correct citation requires accurately providing key details, such as the author(s) name(s), the title of the work, and various numerical or alphabetical constants. If these details are not presented correctly, the citation system fails to function as intended. A simple example is the publication year: if misread or misspelled, like 2001 instead of 2010, it could lead to missing the reference entirely.

The issue becomes even more problematic with alphabetical constants, such as names and titles, which may be recorded or presented in different forms, making it difficult to identify the publication. For instance, the author of this book could have his name written in several variations:

Michel BAKNI *Michel B.* *M. Bakni*
Michel N. Bakni *Bakni, Michel*
B. Michel *Michel Nicolas Bakni*

Theoretically, there is no limit to the types of errors that can arise in this context, even when using Latin scripts only. The issue becomes even more complex when dealing with different writing systems, such as Arabic or Chinese, where variations in names or titles can create further confusion.

This problem also affects book titles, article titles, and institution names. For example, the title “Introduction to the Scientific Method” may refer to several published books, written by different authors in different years and locations.

In simple terms, names, especially alphabetical ones, are not reliable for uniquely identifying objects. Therefore, a system is needed to create, store, and

manage numerical or alphanumerical[129] identifiers to recognise objects uniquely. This is the purpose of authority control.

Identifiers are applied to books, academic articles, people, and entities. In fact, such systems are not limited to the scientific field. They are also used in everyday life, like in car registration plates.

In the next section, four commonly used identifiers will be discussed: the International Standard Book Number (ISBN), the Online Computer Library Centre (OCLC) identifier, the Digital Object Identifier (DOI), and the International Standard Serial Number (ISSN).

ISBN

ISBN stands for International Standard Book Number. It is a unique identifier for a specific edition of a book, meaning all copies of the same edition share the same ISBN. If a book has multiple editions, each

[129] Alphanumerical means that the identifier contains both letters and numbers.

edition will have a different ISBN. This also applies to print and digital versions, as they are considered different editions and will therefore have separate ISBNs. Typically, an ISBN appears as a barcode on the back cover of a book.

The ISBN system was established in 1970 and is now used worldwide. It is uncommon to find a published book today without an ISBN. The system is managed by the International ISBN Agency, which operates through national branches in various countries. Publishers and independent authors apply to these agencies to obtain ISBNs for their works.

An ISBN consists of 13 digits, although older books, published before 2006, have a 10-digit ISBN, as the system was expanded that year. The final digit of an ISBN can sometimes be an “X”, which represents the number 10, a practice based on Roman numerals. The digits in an ISBN are not randomly assigned, they are divided into five sections that indicate the

country, the publisher, and the specific title (Figure 6-5).

Figure 6-5. An ISBN barcoded

OCLC

OCLC stands for Online Computer Library Centre. It is an identifier for a specific copy of a book in a public library, meaning that even two copies of the same edition will have different OCLC identifiers. This system, managed by Online Computer Library Centre, is not limited to books, it also includes academic articles, maps, and online resources.

The OCLC system, also known as WorldCat,[130] was established in 1998. It allows member libraries to synchronise their local databases with a unified global database maintained by OCLC, which is freely accessible to the public.

The structure of OCLC numbers is more complex compared to ISBN. However, it is generally not a primary concern for researchers.[131] An OCLC number consists of 5 to 10 digits. For instance, 729551189 is the OCLC identifier for a copy of the 3rd edition of the Oxford Dictionary of English, published by Oxford University Press in 2011.

DOI

DOI stands for Digital Object Identifier, which is used to identify objects in the digital world. Academic articles, e-books, and other digital content can have

[130] Check https://www.worldcat.org.
[131] Refer to [WEB09] for more details.

DOIs, which can typically be used to create hyperlinks that direct users to the resource online.

The DOI system was established in 2000, following the ISO 26324 standard set by the International Organisation for Standardisation (ISO). It is managed by the International DOI Foundation. Publishers, institutions, and independent authors pay to be assigned DOIs.

A DOI consists of two parts: a prefix and a suffix, separated by a slash. Both parts are case-insensitive and can contain characters, including dots. The prefix is assigned by the foundation to the registering entity, while the entity assigns the suffix to uniquely identify its objects. For example, the DOI Handbook has the DOI “10.1000/182”,[132] where “10.1000” is the prefix, and "182" is the suffix.

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[132] A DOI can be turned into a link to webpage by adding it to “https://doi.org/”. This will create a URL that redirects the user to the digital object it identifies, making it easy to access the resource online.

ISSN

ISSN stands for International Standard Serial Number. It is an identifier for serial publications like academic journals, introduced in 1976.

The ISSN consists of eight digits, split into two groups of four, separated by a dash (e.g., 1660-4601). The first seven digits uniquely identify the series, and the eighth is a check digit, which can be 0-9 or an "X" to represent 10, calculated using a specific algorithm.

ISSN is managed by the ISSN International Centre. Although journals must pay for an ISSN, the system offers a publicly accessible database.[133]

Handling sources

Classification

Sources are categorised based on the number of steps a person takes to reach the original piece of information.

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[133] Check https://www.issn.org.

In Figure 6-6, the subject being studied is represented by a black circle in the centre. The further away a source is from this point, the higher its classification. The three types are: primary, secondary, and tertiary sources.

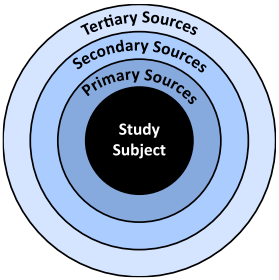

Figure 6-6. Classification of research sources

Primary sources are directly linked to the subject being studied. They include individuals who have direct experience with the subject, so their accounts or information may be biased and need to be handled with caution. This is especially true for eyewitnesses of shocking or violent events, such as natural disasters or crimes. Primary sources also include scientific research from experts closely involved with the subject. These studies should be approached

carefully as well, as they may not have undergone peer review or could contain errors.[134]

Secondary sources are created by individuals who did not have direct contact with the subject. Instead, they relied on information from people or works that did. This makes them one step removed from the original subject, which can be a two-edged sword.

On the downside, secondary sources may contain inaccuracies due to misinterpretation or incorrect understanding of the original information. Therefore, it is important for researchers to verify the reliability of secondary sources. On the upside, secondary sources can provide a broader perspective on the subject, allowing for a more balanced understanding

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[134] During the COVID-19 pandemic, The Lancet published a journal article on the use of hydroxychloroquine on 22 May 2020 [ARE18]. Following significant criticism of the study's methods and findings, three of the four authors reviewed the work and requested its retraction. The article was retracted on 4 June 2020. Although still accessible to the public, it is now marked with the keyword “RETRACTED”, refer to [WEB10] for checking.

by filtering out bias or extreme reactions. Surveys, as discussed in Chapter 5, are examples of secondary sources, as they collect and summarise the findings of primary research.

The third type of source is known as tertiary sources, which are two steps removed from the original subject. While these sources are appropriate for general public use, they often provide a broad overview rather than detailed or precise information, making them less suitable for in-depth research. Tertiary sources are helpful for gaining a general understanding of a subject but lack the specificity required for solid academic study. Examples include encyclopaedias and dictionaries.

Any source that does not fall into the primary, secondary, or tertiary classification should not be considered for research purposes.

Properties

Reliability

Reliability refers to how trustworthy a source is, though it cannot be measured precisely. Instead, it must be assessed based on various factors. A source can be considered reliable, questionable, or unreliable. Only reliable sources should be cited in research.

One key factor in evaluating reliability is the method used to create the source. Scientific sources strictly follow the scientific method, which involves defining a problem, building the state-of-the-art, forming a hypothesis, conducting tests, presenting results, analysing them, and drawing conclusions. A source that focuses mainly on results without explaining the method is not scientific.

Another important factor is the publication process. Scientific works typically undergo peer review and thorough editing before being published. The more

transparent the review process, the more reliable the source.

Other elements that help determine reliability include the reputation of the publisher, the institution where the author works, and the qualifications of the researcher. All these factors should be checked when assessing the reliability of a source.

Independency

For a source to be credible, it must be independent of the subject it discusses. This means the author should present information objectively, focusing solely on facts and not personal opinions. This principle can be applied to exclude promotional materials from research, such as content that encourages people to buy a product, support a political movement, or join a religious group.

In this context, the term “conflict of interest” refers to the idea that authors should have no personal influence on the materials they produce. For

instance, large companies or industries may attempt to influence research that could negatively affect their products, often using financial or indirect means.[135] Therefore, when scientific research is published, authors typically declare that they have no conflicts of interest.

In some situations, there may be only one source of information that is directly connected to the studied subject, such as government reports, especially on sensitive or controversial topics. In these cases, the information should be handled cautiously and attributed to its source as a perspective on the issue, rather than as an absolute fact.

Assessing the independence of a source is not always straightforward. A reliable approach is to avoid self-published materials on controversial topics. It is also

[135] For example, climate change denial represents a persistent crisis driven by pseudoscientific research or invalid interpretations of data. The primary beneficiaries of this denial are the oil industries.

helpful to ensure that the article was published in a journal with a genuine peer-review process. The credibility of the authors, their institutions, and the journal's reputation are key factors to consider.

Verifiability

Verifiability refers to the ability for the sources used in scientific work to be accessible to the public, allowing others to confirm the author's claims. In this context, “accessible” means open to public, though not necessarily free. Some sources may require payment for access, while others may need special permissions, such as documents stored in archives under controlled conditions. However, these access requirements do not make a source unverifiable.

For books and academic articles, a confirmation that they have been officially published is needed, as the mere existence of PDF files in the internet is not proof of publication. Checking international identifiers, like OCLC, helps confirm that third parties have verified the published version. For web pages, either the live

page or an archived version must be accessible for the source to be considered verifiable.

Types

Not all sources of knowledge are appropriate for use in research. Sources must be scientific, verifiable, and published in a trustworthy medium by individuals who have no conflict of interest concerning the subject under study.

Below is a brief list of sources that meet these criteria, which will be discussed in the following sections. Table 6-2 compares the citation requirements for different types of sources, highlighting the key information needed for accurate citation.

- **Peer-reviewed articles**, including both conference and journal articles, are essential sources for research as they undergo a peer-review process. This process excludes essays

and opinion articles from being included in this category.

While conference articles are generally considered primary sources, journal articles are typically secondary sources. Scientific articles usually focus on specific research topics, detailing the problem, method, and results. These articles are often concise, typically 6-8 pages long, but can sometimes extend to 20 pages or more, especially in the case of surveys.

When citing journal articles, it is crucial to include the name of the journal, volume, issue, and the page numbers where the article appears. For conference papers, the citation should include the conference name, year, and page number. In both instances, the citation must also include the authors' names, publication date, and unique identifiers, such

as ISSN for journals, ISBN for conferences proceedings, and DOI for both.

- **Books**, particularly high-level scientific works by reputable authors and published by well-known academic publishers,[136] are valid sources for research. However, books of a literary nature, educational textbooks for schools, and works aimed at popularising science are excluded.

  High-level scientific books are generally considered secondary sources, providing in-depth explanations of specific phenomena or concepts. These books must be thoroughly referenced and strictly follow the scientific method, often written by multiple authors and reviewed independently.

[136] An exception is self-published books, especially with the rise of open access through Creative Commons licences, where more scientists are sharing their work for free.

Dictionaries, encyclopaedias and reference handbooks also fall under this category but are considered tertiary sources. They usually provide summary information and lack detailed references.

When citing books, it is crucial to specify the page where the information is found, and if the book consists of multiple volumes or editions, the exact volume and edition should also be included. Other essential citation details include the author(s) name(s), complete title, publication year, publisher, publication place and ISBN.

- **Research reports**, this category includes documents published by research institutions or governmental agencies to address specific research questions. These reports are often technical and detailed but may not undergo an independent peer-review process,

meaning they could contain biases or conflicts of interest.

Research reports are considered primary sources, as they are produced directly by researchers involved in the study. In many cases, a large team of researchers contributes to the report, and their names are typically listed at the beginning. However, when citing such a report, it is not necessary to list all contributors if there are more than five.

Although the authors' names can be omitted in citations, the name of the institution and the publication date must always be included. Research reports may also have unique identifiers assigned by the institution, which are essential to include for accurate citation.

- **Ph.D. theses**, these are comprehensive dissertations written by early-carrier researchers to earn a Doctor of Philosophy (Ph.D.) degree in a specific scientific field. A

thesis presents in-depth research conducted according to the scientific method, including a review of current knowledge, hypotheses, testing, analysis, and conclusions. Typically, completing a Ph.D. takes around three years. Each thesis is evaluated and approved by an independent jury and then published under the name of the university where the research was performed.

Ph.D. theses are valuable resources for research but should be used cautiously. As primary sources, they often represent the cutting edge of knowledge in their specific area at the time of publication. However, they may become outdated or be superseded by newer research. Some theses might propose bold theories that are later significantly revised.

When citing a Ph.D. thesis, it is important to include the publication date and the

university where the research was conducted. Additional citation details include the author's name, the title of the thesis, and any relevant identifiers.

- **Web pages**, this category includes materials that are available exclusively in digital form on the Internet. More specifically, a webpage is a document on the World Wide Web (WWW) accessible via a unique address called the Uniform Resource Locator (URL).[137] The issue of citing web pages in research is debated, some argue they should never be cited, while others believe they can be cited under certain conditions.

  Opponents of citing web pages claim they are unreliable. Since webpages are stored on private servers, they can be removed edited,

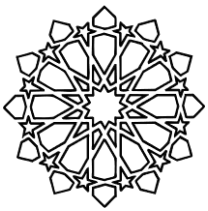
[137] A URL (also known as a web address) is a unique string of characters used to identify a web page. It was introduced in 1994 by Tim Berners-Lee (1955-). For example, a typical URL might look like this: http://www.example.com/index.html.

or become inaccessible for various reasons, making the citation invalid. Supporters argue that special services, such as the Internet Archive, create dated backups of web pages, making them accessible even after the original page is no longer available. However, critics point out that the archive itself relies on servers that could also be shut down.

If a web page is cited, it should be accompanied by three dates and two URLs. The dates include the publication date of the original web page, the date it was accessed, and the date when it was archived. The URLs include both the original web page address and the archive link. Additionally, citation details such as the title, website name, and author(s) names, if available, should be provided.

Table 6-2. Required bibliographical information

Type	Required bibliographical information (if exist)	
Peer-reviewed article	• Author name(s) • Title • Publication date (Month/year) • Journal name or conference title	• Publisher • Volume • Issue • Page numbers • Publication identifies (e.g. ISSN, DOI, ISBN)
Book	• Author name(s) • Title • Publication year • Edition	• Publisher • Place of publication • Publication identifier (e.g. ISBN, OCLC)
Research report	• Author name(s) • Title • Publication year • Publisher	• publication Place • Publication identifier (e.g. ISBN, OCLC)
Ph.D. thesis	• Author name • Title • Publication year	• Institution name • Publication identifier
Web page	• Author name(s) • Page Title • Publication date • URL	• Website name • Access date • URL archive • Archive date



On the ethics of research

Introduction

In the context of scientific research, ethics refers to the principles and standards that guide researchers in conducting studies responsibly and morally. These standards define how researchers adhere to professional norms and avoid misconduct practices such as fabrication, falsification, and plagiarism.

Ethics also ensures that researchers conduct their work in a way that respects the dignity, rights, and welfare of all humans involved, as well as other living beings such as animals and plants. In recent decades, ethics have expanded to include the protection of the environment.

Science is not an evil tool meant to destroy the world, nor is it a good tool meant to make it a better place. It is simply an objective method with steps that can be used in both ways. Science can create destructive weapons that threaten all life on Earth, but it can also

resolve problems like fighting diseases, ending hunger, and exploring space. The impact depends on who uses science, not on science itself. This is what makes the ethics of science essential to research.

This chapter covers the definition of ethics in scientific research, the key issues it addresses, which practices scientists should avoid, and how to integrate ethics into research.

Definition

Philosophy forms the foundation of all sciences. It requires only human thought and does not rely on other sciences or branches of knowledge. Philosophers classify philosophical topics into four main areas: epistemology, ethics, Logic, and metaphysics. Ethics, also known as moral philosophy, is further divided into three branches: normative ethics, applied ethics, and metaethics. Normative ethics explores how individuals should behave and act within society. In contrast, applied ethics

examines the appropriate behaviour in specific situations, such as conducting a research. Finally, metaethics investigates moral phenomena, seeking to understand the nature, scope, and meaning of moral judgments.

Figure 7-1 shows the main branches of philosophy and the subdisciplines of applied ethics. It demonstrates that applied ethics is a broad field with various subdisciplines, including, for example, bioethics and professional ethics. Bioethics deals with moral issues related to living beings, such as humans (medical ethics), animals, and the environment. For example, medical ethics addresses issues like abortion and human cloning research, while animal ethics looks at the morality of animal testing. Environmental ethics covers moral challenges like nuclear waste production. Professional ethics involves the standards of behaviour expected from professionals, including

how researchers interact in the workplace and conduct their studies.

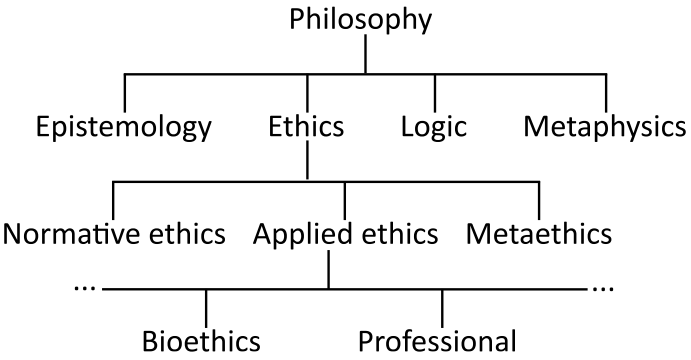


Figure 7-1. Philosophy and its branches

Thinkers and philosophers do not agree on a single definition of morality. However, they generally recognise three systems. The first, known as the feminine system, is based on gentleness and compassion and considers love as the ultimate virtue. The second system, called the masculine system, emphasises severity and firmness, viewing power as the key virtue. The third system argues that virtue is

based on reason, which is the only thing capable of judging what is good and bad.[138]

In research, ethics are a set of moral principles that ensure studies are conducted responsibly and with integrity, respecting the rights and welfare of participants, fellow researchers, the environment, and society. Science, as an impartial tool, relies on ethics to guide it and prevent misconduct.

Historically, medicine is the field where ethics have developed the most. Early concerns focused on the limits of patient testing and human dignity, particularly regarding autonomy.[139] However, other disciplines also face moral dilemmas, especially technology, with the rapid rise of Artificial Intelligence (AI) in recent years.

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[138] For more details see p. 197 in [BKE18].

[139] Historically, state-supported large-scale ethical violations in research were a major reason for developing ethical codes [ARE19]. For example, Nazi human experimentation was deemed a crime against humanity and led to the creation of the Nuremberg Code, which established principles for human experimentation [ARE20].

The advancement of information technology drives the evolution of research ethics today. As technology progresses, new ethical questions arise, such as the legal responsibility of self-driving cars in case of accidents, the privacy limits of facial recognition and deepfake technologies, and the accountability of AI decision-making systems used in warfare.

Major issues

Ethics is a broad branch of philosophy, which is of a theoretical nature. However, in research, the emphasis is more on practical applications, such as protecting the rights of participants, rather than on theoretical questions like the origins of ethics or defining good and bad.

This section covers various aspects of applied ethics in detail, including honesty, objectivity, transparency, copyrights, environmental responsibility, and data protection. The first three focus on research conduct,

while the latter three relate more to the research process itself.

Each section begins with an introduction that defines the aspect and its scope. This is followed by examples of well-known scandals or controversies that highlight the impact of that ethical issue on research. Finally, recommendations are provided to help researchers adhere to ethical standards.

Honesty

Science is fundamentally grounded in empirical evidence, leaving no room for emotions or subjectivity. and, the research process must is expected to with truthfulness and transparency. Researchers must to maintain honesty with themselves, the scientific community, and the public.

There are numerous practices that can undermine honesty in research, most notably:

- Falsifying or incompletely presenting research methods to prevent others from

replicating the work, thereby keeping potential achievements solely for oneself.

- Deliberately misinterpreting results or collected samples, which constitutes cheating and violates research integrity.
- Stealing others' findings, including research subjects, methods, and results.
- Unfairly securing grants and funds, which violates the principle of equal opportunity.

Dishonesty can severely backfire on researchers, potentially setting back entire fields of study. Just one instance of dishonesty can undermine years of work and weaken the fundamental trust that science relies on.

Public trust in science is heavily influenced by researchers' honesty. When the public sees scientists as trustworthy and ethical, they are more likely to support scientific efforts and accept scientific

findings.[140] This trust is crucial for public policies, health recommendations, and environmental actions based on scientific evidence. Conversely, when dishonesty or misconduct is revealed, it can lead to widespread skepticism and cynicism about scientific research, resulting in resistance to scientific advice, reduced research funding, and decreased public engagement with science.

A well-known case of fraud that severely impacted a scientific field is the Piltdown Man hoax. In 1912, amateur archaeologist Charles Dawson claimed to have discovered the "missing link" between early apes and humans. The fraud gained serious acceptance when findings were published in the reputable "Quarterly Journal of the Geological

[140] Misinformation, conspiracy theories, and lack of trust in scientific findings posed significant threats to public health and undermined governmental efforts globally during the COVID-19 vaccination campaign in 2021. For more details, see [BKE19].

Society".[141] However, the discovery was inconsistent with the existing knowledge of evolution and the archaeological record at that time. It took nearly 40 years for "The Time" to reveal that the Piltdown Man case was a fraud.[142] This incident still significantly affects people's acceptance of the theory of evolution in the United Kingdom, particularly due to the long time it took to expose the hoax.

Maintaining honesty in research not only enhances the credibility of individual studies but also strengthens the foundation of scientific knowledge upon which future research builds. Achieving this in research involves several key practices:

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[141] An article titled: "On the Discovery of a Paleolithic Human Skull and Mandible in a Flint-bearing Gravel Overlying the Wealden (Hastings Beds) at Piltdown, Fletching (Sussex)" was published in December 1912, authored by Charles Dawson and Sir Arthur Smith Woodward, a fellow of the Royal Society of London, See the [ARE21] for more details.

[142] The Time's article was published on the 30th of November 1953, it was titled: "Science: End As a Man", refer to [WEB11].

- **Comprehensive data presentation:** Researchers should avoid selectively presenting results that support a particular hypothesis while omitting contradictory findings. All data points, even those that may not align with initial expectations, must be included and discussed. This practice prevents bias and ensures that the conclusions drawn are based on a comprehensive analysis of all available evidence.
- **Accurate reporting of methods, data, and findings:** Researchers must precisely describe the procedures they follow in conducting experiments or investigations. This includes detailing the equipment used, the parameters measured, and the conditions under which experiments were carried out. Such transparency allows others to replicate the study and verify its outcomes. Transparency will be discussed in detail next.

- **Avoiding misrepresentation and exaggeration:** this is achieved by presenting findings accurately without overstating their significance. Researchers should avoid making sweeping generalisations beyond what the data can support. Scientific language should be used to describe the implications of the findings, acknowledging any limitations or uncertainties inherent in the research.

Objectivity

Objectivity implies that the researcher maintains complete independence from the subject under study. The researcher should have no material or moral gain or interest in the research outcomes. Objectivity is essential for unbiased judgment of the obtained results, ensuring they are analysed as they are, without any intention to amplify or diminish their impact.

When a researcher violates objectivity, they become subjective. There are several sources of subjectivity, most notably:

- **The Researcher himself**: Sometimes, the researcher may have personal hypotheses and may attempt to prove them despite contrary evidence from multiple studies by other researchers. In this case, the researcher is trying to prove that the ideas were valid for no reason except that they are his.

  In other cases, supervisors pressure researchers to complete their research quickly for financial or academic reasons, such as the end of a contract or the academic year. In this situation, the researcher may prioritise finishing on time, which can conflict with the research goals if delays or the need for additional tests or analysis arise.
- **Ethical and cultural bias:** This occurs when the ideas from the social environment where

the researcher resides, or has resided, influence the research, often manifesting as prejudgment without solid evidence.

For example, race science[143] was a common and widely accepted practice in Europe and the United States until the end of WWII. Despite the lack of empirical evidence to support its claims, researchers reflected the social classifications of their era.

Another example is the biblical expeditions[144] in the Holy Land in the mid-19th century.

[143] Also known as scientific racism and biological racism, a pseudoscience claims that the humans are divided into biologically distinct categories called "races" and that empirical evidence exists to support or justify racial discrimination, racial inferiority, or racial superiority. Refer to Vol. 2, p. 779 in [ABE20] more information.

[144] For example, in 1863, Louis Félicien de Saulcy (1807 – 1880) received permission from the Ottoman authorities to excavate in the Holy Land. He discovered the Tombs of the Kings in Jerusalem and mistakenly identified them as the tombs of the House of David (circa 950 BCE). Later, it was determined that the tomb belonged to Helena of Adiabene, dating to around 56 CE, over 900 years after de Saulcy's estimate. The sarcophagus is now housed in the Louvre under Accession Number AO 5029, see [WEB12] for more details.

These expeditions aimed to follow the biblical narrative despite the lack of historical evidence. As research progressed, archaeological findings increasingly contradicted the biblical narrative. By the end of the century, archaeologists recognised that while some biblical records might have some historical basis, they were far from being historically accurate.

- **Financial pressures from funders:** Entities that provide funds might try to manipulate the results to serve their own interests. Researchers in such situations may interpret data under the risk of having their findings suppressed, potentially leading to biased results.

  In the pharmaceutical industry, a company funding research on its drugs has a direct interest in studies that demonstrate the drug's efficacy and safety. In environmental

research, industries known to cause environmental harm, such as the oil and gas industry, also fund studies. These pressures might not aim to deny negative environmental effects but rather to downplay them or highlight economic benefits.[145] In both examples, the financial interests of the funders can create conflicts of interest, leading to compromised research integrity and potentially misleading conclusions.

Achieving objectivity is a complex process that demands intentional and thoughtful effort. The following checklist can help avoid subjectivity:

[145] Refer to Clair Cameron Patterson (1922–1995), an American geochemist who began a campaign in 1965 to remove lead from gasoline [ARE22]. Despite being a leading expert in his field, major industry players pressured to exclude him from the National Research Council Panel on Atmospheric Lead Contamination. Nevertheless, Patterson persisted and eventually proved that lead levels in blood, soil, and air were extremely high and dangerous to humans. This led to the mandate for unleaded gasoline, resulting in significant industry changes for public health, check [ARE23] for details.

- **Separating facts from opinions:** It is crucial not to mix opinions or desires with findings. There should be a clear distinguish between facts and opinions to avoid subjectivity. It is recommended for researchers to verify facts from multiple reliable sources, especially if the information aligns with the researchers' beliefs or predictions.
- **Relying on empirical evidence:** This means strictly using systematic observation or experiments to gather data. An objective researcher accepts only what has been tested and proven to produce consistent results that can be predicted and understood through mathematical equations or models. The use of critical thinking is crucial in this context, as it ensures rational,

skeptical, and unbiased analysis and evaluation of the subject being studied.

- **Follow the peer review process:** As discussed earlier in Chapter 4, peer review is an essential mechanism where independent experts in the same field evaluate the work, assessing both its validity and objectivity. The process should be immune to any exterior influences and the identities of both reviewers and authors are typically kept hidden to maintain objectivity.

Transparency

Transparency in research involves making every part of the research process open and accessible to everyone, including the general public, peer researchers, and stakeholders. This means sharing detailed information about the research methods

followed, data collected, and analyses conducted, so that other researchers can reproduce the work or build upon it, and the public can understand its context.

As discussed in Chapter 4, reproducibility is the ability of independent researchers to obtain the same results using the same methods, data, and conditions as the original study. Reproducibility ensures the validity of findings and helps reduce errors. It is a fundamental aspect of the scientific method, and transparency is key to achieving it.

A well-known example highlighting the importance of transparency is the Climatic Research Unit (CRU) email controversy, commonly referred to as Climategate.[146] In 2009, thousands of emails and files from the CRU at the University of East Anglia (UEA) in the UK were hacked and made public. The content of these emails sparked widespread controversy, with

[146] See more details on this incident in [ARE24].

climate change skeptics accusing CRU scientists of withholding data from other researchers, misrepresenting the data, and attempting to influence the peer-review process to silence the opposite perspectives.

Multiple independent investigations were conducted,[147] all of which concluded that there was no evidence of fraud or scientific misconduct. However, despite these findings, the incident fuelled significant skepticism about the validity of climate science. As a result, the perceived lack of transparency severely damaged public trust in a crucial issue and provided long-lasting support to climate change skeptics.

[147] There were eight independent committees who looks into the subject: (1) House of Commons Science and Technology Committee (2) Independent Climate Change Review (UK) (3) International Science Assessment Panel (UK) (4) Pennsylvania State University first panel & (5) second panel (US) (6) United States Environmental Protection Agency (US) (7) Department of Commerce (US) (8) National Science Foundation (US).

Researchers can take several steps to avoid secrecy and promote transparency:

- **Maintaining a Transparent Research Log**: Many laboratories keep a research diary that is accessible to everyone in the lab or even the general public. This diary includes a detailed record of the research process, decisions made, and any changes to the methods. These entries offer a comprehensive overview of the research's progress.
- **Open Access**: It involves making raw data, methods, and protocols publicly available in repositories so that others can verify and reanalyse the findings. By providing detailed descriptions, other researchers can replicate the study. Open access also includes publishing results in open-access journals, ensuring that research is accessible to a broader audience without paywalls. In the

last decade, this practice has becoming increasingly common in research.

- **Disclosure of Funding**: Researchers must identify their sources of funding, with no ambiguity, to avoid potential conflicts of interest and maintain the integrity of the research.

Copyrights

Creative works are protected by legal rights that last many years after they are published or after the author's death.[148] This means using these works or materials based on them requires written permission from the rights holder. The rights holder could be the author, their heirs, or an entity like a publishing

[148] There is no uniform law around the world to protect intellectual property rights, and laws vary by country in many details, such as what constitutes a creative work and the duration of protection, which can be up to 100 years after the death of the author or the publication date, if the author is unknown. See [WEB13] for more information on copyright status by country.

house. Using these materials without permission breaks the law and may result in fines.

Creative works, includes, but not limited to texts, images, videos, drawings, computer programs, artwork, and architecture. This protection is often indicated by a © symbol, clearly mentioned in a text form. However, even without any of these, the work is generally assumed to be protected unless stated otherwise.[149] The duration of legal protection varies depending on the type of work and the country. After this period, the work enters the Public Domain (PD) and can be used by anyone without legal consequences.[150]

A common copyright violation among researchers is plagiarism. This happens when a text is copied from

[149] This book is published under a Creative Commons license. For details about rights and obligations, see the license page.

[150] For example, the copyrights on Mickey Mouse, the famous Disney character, expired on January 1, 2024. This means that from this date, anyone can use this character for any purpose, including commercial uses, without any legal consequences.

other works without citation, making it seem like the copier is the original author. If needed, text from the original work can be quoted directly, or it can be properly rephrased while keeping the original idea. In both cases, the original author must be cited in the text using the appropriate citation style.

To avoid violating copyrighted materials, a researcher should:

1. Verify the copyright laws in their own country and the country where the work he will use is published. This helps understand the legal status of the work and how to use it without violation.
2. Obtain permission from the copyright holder if the materials are to be used commercially.
3. If the researcher has no permission, but there is an urgent need to use the materials non-commercially, a proper citation to the original work and author can work.

Environment

There is no alternative to Earth. If the planet is ruined and becomes uninhabitable, there is no plan B. Therefore, research must prioritise environmental sustainability. This means guiding researchers to conduct studies that balance the pursuit of knowledge with the responsible management of natural resources and respect for all forms of life. Research is a key driver of industry. Over the past decade, awareness of human-made pollution's impact on the planet has increased, largely due to the widespread effects of climate change.

However, Companies that fund research are driven by profit and often view nature solely as a resource to be exploited for maximum gain. This perspective should not influence research. Instead, research should adhere to the principle of non-maleficence[151],

[151] Also known in Latin as “Primum non nocere”, this core principle of medical ethics states that a physician must not harm the patient. Over time, the scope of this principle has been

which focuses on minimising harm to ecosystems, wildlife, and communities, in the short and long term.

Environmental crises, such as pollution and biodiversity loss, have significant effects across both space and time. While the immediate impact might be confined to a specific area, its consequences are global. For instance, the melting of ice in the North Pole is not restricted to that region alone. It causes sea levels to rise worldwide, threatening coastal cities in both industrial and growing countries. Environmental crises are also generational, meaning their effects are not limited to current population, but extends to impact future generations as well.

Renewable energy[152] is a research field that has expanded rapidly due to increased environmental

broadened to apply not only to physicians but also to researchers across all fields, extending its relevance to the protection of the environment as a whole.

[152] Also known as green energy, a field of electrical engineering that involves the study of human-made systems designed to collect and distribute energy from natural renewable resources,

awareness. Although it is a branch of electrical engineering, it remained relatively obscure before the 2000s. However, in less than 20 years, interest in this field has surged, making it a hub of innovation and research. The International Renewable Energy Agency (IRENA) reported an annual average growth of 112% in the number of patents filed in this field between 2000 and 2016, with the total number of related patents rising from around 11,000 in 2000 to over half a million by 2016.[153]

Incorporating sustainability into research can have a significant impact on the results. Introducing a focus on eco-friendly solutions allows for a shift from traditional methods and themes. This approach requires researchers to be flexible and adaptable having the capacity to integrate new practices into their own research models.

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such as solar, wind, and hydropower. The goal is to enhance the efficiency of these systems, reduce their costs, and make them easier to install and use.

[153] Full report can be found in [WEB14].

Additionally, many changes in the working environment can reduce the ecological impact of the research, as a process itself. This includes adopting ecological policies such as:

- **Digital Research:** This involves moving away from traditional resource use and embracing green technologies in everyday research. For example, shifting to paperless meetings and communication instead of relying on paper notes and postal mail. It is also possible to publish results in only-online academic journals. This can help reduce the number of printed papers, thereby reducing the environmental impact of research.
- **Energy Efficiency**: This involves improving the energy use of lab equipment, computers, cooling systems, and lighting. New policies can be developed to ensure that equipment is turned off when not in use and to implement

flexible working hours that align with daylight hours, thereby reducing energy consumption.

Privacy and data protection

When people participate in a study, personal data may be collected for research purposes. This can range from general information like names, phone numbers, or addresses, to more sensitive data such as medical records or political views. Therefore, it is crucial to take special precautions to protect participants' privacy.

While awareness of the importance of privacy, particularly digital privacy, has significantly increased in the last decade, there is still no universal standard for data protection worldwide. Laws vary from country to country, and sometimes even between states within the same country. Therefore, it is inevitable to thoroughly understand and comply with local regulations regarding the collection, storage, and sharing of personal data for research purposes.

The Facebook-Cambridge Analytica data scandal is an example that illustrate how data privacy violations can escalate on a global scale in the digital age, affecting millions of people.[154] The scandal was a global violation of Facebook user privacy in the mid-2010s. Cambridge Analytica, a British political consulting company, developed an application that generated quizzes for Facebook users. However, the application not only gathered data from users who took the quiz but also accessed personal information from their friends and collected additional information from participants' profiles beyond the quiz questions. This extensive data collection occurred without the explicit consent of the majority affected. The data was then analysed to understand users' personalities and predict their choices.[155]

[154] A detailed background can be found in [ARE25].
[155] More on the Psychological targeting in [ARE26].

In total, data was collected from around 87 million Facebook users.[156] The scandal had significant political implications worldwide. There is ongoing debate about whether the Trump presidential campaign[157] in 2016 and the Brexit campaign[158] in the UK benefited from this data analysis to design more targeted and effective campaigns.

Protecting the privacy of collected data is the researcher's responsibility. The process begins with thoughtfully considering what information is necessary to collect. Any redundant or irrelevant data that does not contribute to the research should not be gathered. The data collection process should be carefully designed to ensure the anonymity of

[156] This number was provided by Mike Schroepfer, Chief Technology Officer of Facebook, in a 2018 article on the Meta Newsroom blog, see [WEB15]. However, the actual number could be higher, as this value was based on a dependent source

[157] Donald John Trump (1946-) the 45th and the 47th president of the United States of America.

[158] Abbreviated from "British exit", the acronym refers to the United Kingdom's withdrawal from the European Union (EU), following a referendum held in 2016.

participants, making sure that no individual can be identified from the collected data.

When processing data, it is crucial to ensure that it is not shared with unauthorised individuals, whether within the researcher's institution or with any third party involved in the research. Additionally, uploading the results to the public internet for sharing purposes is strictly prohibited.

Another important aspect that should not be underestimated is the consent of the participants. All individuals involved in any experiment or survey must be fully aware of their participation and have the right to refuse or withdraw at any time. The entire process must be transparent, and participants need to clearly express that they are voluntarily taking part. In some countries or situations, it may be necessary to obtain written permission signed by each participant.

The following checklist summarise the previous paragraph in a form of a verifiable checklist:

- **Informed consent**: The researcher must provide participants with clear and comprehensive information about the research. If sensitive data is involved, obtaining signed written consent is essential.
- **Anonymisation**: To protect participant identities, the researcher should ensure that individuals cannot be identified from the data. Using pseudonyms or codes instead of real names is recommended.
- **Data minimisation**: The researcher should limit data collection to only what is necessary for achieving the research objectives.
- **Secure data storage and sharing**: Access to data should be restricted to authorised individuals. This can be done by securely storing physical documents in locked locations and digitally protecting data through encryption and secure methods for data transfer and sharing.

Ethics integration in the research

With all the previously mentioned issues in the hand, ensuring research integrity within an institution is a challenging task. Typically, any institution engaged in research must have an independent body, often called the Institutional Review Board (IRB) or Ethics Committee, that oversees ethical guidelines and regulations customised to the institution's specific context. This committee also ensures that all research activities are conducted ethically and responsibly.

There is not a single, universal set of ethical regulations that every institution must follow. Instead, IRBs establish policies, procedures, protocols, and standards that align with the institution's context, comply with local laws, and meet international requirements. These regulations are designed to protect the rights and welfare of research participants, other living beings, and the

environment. Additionally, these guidelines should be flexible and able to adapt to changes over time.

One of the IRB's primary responsibilities is to ensure data confidentiality by overseeing how researchers follow procedures and comply with local laws when handling sensitive information. For instance, institutions that manage medical records in the US must strictly adhere to the Health Insurance Portability and Accountability Act of 1996 (HIPAA).[159] Violations of this law can result in civil or criminal penalties for the institution or individuals involved.

Similarly, the General Data Protection Regulation (GDPR),[160] in effect across the EU since May 25, 2018,

[159] The EU regulation governing the processing of personal data is formally titled "Regulation on the protection of natural persons with regard to the processing of personal data and on the free movement of such data, and repealing Directive 95/46/EC (Data Protection Directive)". This regulation was established by the European Parliament and the Council of the European Union in 2016, see [WEB16] for details.

[160] The US federal law concerning health information, commonly known as the Kennedy–Kassebaum Act, is officially titled "An Act to amend the Internal Revenue Code of 1986 to improve

must be respected by all research institutions within the EU.

The IRB also examines potential conflicts of interest in research conducted within the institution and assists researchers in resolving any such issues. Additionally, as new technologies emerge, the IRB is responsible for addressing these evolving challenges and providing temporary guidance or procedures. For instance, with the rapid advancement of AI, several copyright issues have arisen concerning works created by non-human entities. Legal cases on such matters can take years to resolve in court. During this time, the IRB, in collaboration with the institution's legal office, plays a crucial role in advising researchers

portability and continuity of health insurance coverage in the group and individual markets, to combat waste, fraud, and abuse in health insurance and health care delivery, to promote the use of medical savings accounts, to improve access to long-term care services and coverage, to simplify the administration of health insurance, and for other purposes". It was enacted by the United States Congress in 1996 [WEB17].

by offering consultations, recommendations, and best practices to navigate the situation.

The IRB also serves an educational role within its institution. For staff or early-carrier researchers, such as Ph.D. candidates or those in higher education, the IRB offers support alongside research supervisors. The committee often organises workshops or educational programs within the institution to introduce new concepts, explain updates to local laws, or simply raise awareness about the importance of ethics in research.

Common ethical violation

Misconduct can happen in the research field. No one, including researchers, is immune to breaking the code of conduct, and ethical violations can occur at any time by anyone.

In the next section, three common violations will be discussed: Fabrication, Falsification, and

Plagiarism (FFP). Each violation will be defined, with a focus on how to be avoided.

Fabrication & falsification

Fabrication involves creating data that was never actually observed or collected during experiments. It is an act of manipulating findings intentionally to direct results in a desired direction. On the other hand, falsification[161] involves deliberately altering collected data to support specific claims or hypotheses. This is not only limited to manipulating the data itself but also extends to modifying the tools used in the experiment or for recording the data in a way that discards unwanted results.

Unintentional manipulation of data can occur due to improper research procedures or lack of skills with equipment, leading to measurement errors or incorrect readings. Failures in controlling

[161] It is important not to confuse falsification with falsifiability, which refers to the ability of a proposition, hypothesis, or theory to be proven false.

experimental conditions can also result in unintentional data manipulation. However, these are not considered fabrication nor falsification because they lack the element of intent.

The Schön scandal in electronics in the early 2000s is an example of data fabrication.[162] Named after Jan Hendrik Schön, a physicist at Bell Labs who worked on organic electronics. The scandal involved Schön publishing numerous papers in high-impact journals like Nature and Science. He claimed to have discovered ways to create organic transistors with unprecedented efficiency. However, other scientists began to doubt his findings when they could not replicate the results. Later investigations revealed that Schön had fabricated and manipulated data in multiple publications, made up experimental results that were never observed, and reused the same data sets for different experiments.

[162] See [ARE27] for details.

As a result, Schön's doctoral degree was revoked for "dishonourable conduct", and dozens of his peer-reviewed papers were withdrawn,[163] severely damaging the credibility of the field of organic electronics worldwide.

The Lancet MMR[164] autism fraud is a prime example of data falsification in medicine. In 1998, Andrew Wakefield[165] and his colleagues published a peer-reviewed paper titled "Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children"[166] in the highly reputable journal: The Lancet. In their study, the authors claimed to find a link between the MMR

[163] In total, Science withdrew nine articles written by Schön, Nature withdrew seven articles written by Schön, Physical Review withdrew six articles, Applied Physics Letters withdrew four articles. All articles written between 2000 and 2002.
[164] MMR stands for measles, mumps, and rubella, three viral diseases that affect humans.
[165] Andrew Jeremy Wakefield (1956-), a former British physician figure known for his fraudulent activities, discredited academic work, anti-vaccine activism.
[166] See [ARE28] for more details.

vaccine and autism, describing a new syndrome they called “autistic enterocolitis”.

Later investigations, led by the UK's General Medical Council (GMC), revealed that Wakefield had falsified the medical histories and diagnoses of the children to make it seem like they were diagnosed with autism shortly after receiving the vaccine. The study suggested that 8 out of 12[167] children were diagnosed with autism, but medical records showed that only one child had autism, and three had not been diagnosed with autism at all. In 2010, GMC found that Wakefield acted dishonestly and misled others in his research. As a result, The Lancet fully retracted Wakefield's publication.

The impact on public health was severe. Wakefield's claims triggered widespread fear and skepticism about vaccine safety, leading to a significant decline in vaccination rates globally. This decline resulted in

[167] It is also important to note that the sample size was too small to draw such a conclusion.

outbreaks of measles, mumps, and rubella, diseases that had been largely controlled through vaccination.

Fabrication and falsification are unacceptable practices and forms of misconduct that should never be committed by researchers. However, unintentional fabrication or falsification can happen due to not following proper procedures and protocols. As discussed earlier, fabrication and falsification mainly involve the integrity of data. Therefore, to avoid unintentional violations related to these misconducts, careful attention must be given to data handling at three key stages:

- **Pre-data acquisition**: Researcher needs to define the methodological steps in details before collecting data, including what to measure, how to measure it, and where to store the results. It is crucial to establish and adhere to the method without making changes during or after data collection to fit the findings.

- **During data acquisition**: Data needs to be stored accurately as it is collected. The storage medium used to store the data has to preserve it, as it is, without changing over time. It is also important to ensure that the speed of data generation is matched by the storage system to avoid data loss or corruption.
- **Post-data acquisition**: This covers the use of appropriate mathematical methods to process the data. It is acceptable to use functions to classify data or to reduce noise, but the parameters of these functions must be set carefully to avoid manipulating the data in a desired direction.

Additionally, it is advisable to have an independent scientific advisor review the research method and ensure that it is resistant to both fabrication and falsification.

Plagiarism

Plagiarism occurs when someone, called a plagiarist, uses words, expressions, or ideas from others without giving them credit, making it seem like their own work. While not usually a crime, plagiarism is taken very seriously in academia because it violates research integrity. Students or professors who plagiarise could be permanently expelled from their educational institution.

In academia, there is no universally agreed-upon definition of plagiarism. For instance, the Honor Code at Stanford University characterises plagiarism as:[168]

"Use, without giving reasonable and appropriate credit to or acknowledging the author or source, of another person's original work, whether such work is made up of code,

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[168] See Stanford university's policies and guidance in [WEB18].

formulas, ideas, language, research, strategies, writing or other form"

Yale, in New Haven, Connecticut, defines plagiarism as follows:[169]

"Use of another's work, words, or ideas without attribution […] using a source's language without quoting, using information from a source without attribution, and paraphrasing a source in a form that stays too close to the original"

On the other hand, at Princeton University, Plagiarism is:[170]

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[169] The text is quoted from Teaching materials for Yale students, refer to [WEB19].

[170] The text is from a document titled "Defining and Avoiding Plagiarism: The WPA Statement on Best Practices", released by the Council of Writing Program Administrators at Princeton University in January 2003, refer to [WEB20].

"The deliberate [use of] someone else's language, ideas, or other original (not common knowledge) material without acknowledging its source"

Plagiarism is not just about copying someone else's writing without giving credit. There are four possible forms of plagiarism, all involving failure to cite the original author, but differing in how they copy the work:

- **Characters-preserving**: Copying the original work exactly, as it is, character for character.
- **Syntax-preserving**: Keeping the original word order when copying but replacing the words with synonyms.
- **Semantics-preserving**: Maintaining the same meanings, order, and narrative of the original work, but using different words and sentence

structures to express it. This kind of Plagiarism includes translation and paraphrasing.

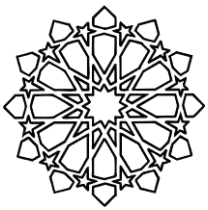
- **Idea-preserving**: Using someone else's main ideas to develop new projects, like startups or research theses.

Given the various definitions and forms of plagiarism, it can be challenging to detect unless it is Characters-preserving. This is also can be achieved using online plagiarism detectors. In other cases, when professors, researchers, or students are suspected of plagiarism, judgments cannot be generalised. Therefore, an internal disciplinary committee, within the educational institution, typically evaluates each case individually to determine if plagiarism has occurred.

Plagiarism must be avoided by all means. The first and most important step is to understand what constitutes plagiarism and what does not. Next, it is crucial to define the research's contribution, assessing its originality compared to existing works.

Avoiding plagiarism does not mean avoiding the use of others' works. Instead, it emphasises the need to properly cite them. Even when paraphrasing or rewording, citation is critical and cannot be ignored. Additionally, seeking permission from original authors to use their works can foster collaboration. However, having permission does not eliminate the need for citation.

Researchers are also advised to use online plagiarism detectors on their own work before submission to ensure it is free from any form of plagiarism.



On writing and publishing

Introduction

The scientific method is an integral process where each step must be executed accurately to achieve reliable results. In Chapter 4, the method was thoroughly discussed, with a focus on its ongoing and cyclical nature. Publishing was identified as the final step that completes this cycle, serving as a crucial communication tool for researchers.

Before publishing any material, the ideas, results, and analysis must be written down in detail and coherently, following the scientific method. Scientific writing emphasises structure and standardisation. Unlike creative writing, where authors can freely express themselves, scientific writing requires authors to be objective and follow a specific set of rules that are widely accepted by researchers.

The importance of publishing lies in how it contributes to the scientific record, particularly through the citation of others' work, which is a cornerstone of the scientific method. For accurate citations, the original work must be published, making the knowledge accessible, verifiable, and properly attributed to the original authors. A robust scientific record is essential for advancing science, as it prevents the redundancy of repeating past work and ensures the progress.

Publication is essential for ensuring reproducibility, a critical feature that defines credible science. In research, publications go beyond merely presenting results. They provide a detailed account of the methods used and the conditions under which the research was conducted. This level of detail allows other researchers to replicate the study and verify the results under the same conditions.

Moreover, publishing reinforces the ethical dimensions of research. As discussed in Chapter 7,

transparency is a fundamental ethical principle. This process helps prevent scientific misconduct, such as data fabrication, falsification, or plagiarism. Additionally, publication serves as a means of sharing knowledge, contributing to the public good and benefiting humanity as a whole.

This chapter covers the scientific style of writing and the publication of scientific works. It starts with general guidelines on scientific writing showing how to avoid subjectivity and adhere to the scientific method. The chapter, and the book, conclude with a detailed overview of different types of publications.

Scientific writing

Scientific communication values consistency and standardisation to ensure clarity and reproducibility.

While there is no universally accepted standard for scientific writing, certain key principles are widely recognised. These include the need for clarity and

precision, maintaining author objectivity, and the importance of proper citations and references.

In the next section,[171] various notes address common writing and formatting challenges researchers may encounter while preparing their final manuscript for publication. Topics include best practices for avoiding unclear wording, choosing fonts and text styles, and tips for using figures and lists effectively.

- **Final format:** The first question to consider before starting to write is whether the final format will be digital or printed. Over the past two decades, there has been a significant shift towards fully digital materials, and scientific publications are no exception. This shift is largely driven by the widespread availability of the Internet and the ease with which digital documents can be shared, stored, and

[171] This is not an exhaustive list, but it does cover many common issues authors encounter when writing and suggests best practices to address them. The most practical use of these notes is to turn them into a checklist for verification.

accessed. However, printed formats remain an option.

In digital formats, there are no strict rules about page order, so aligning the internal cover and chapter starting pages on odd-numbered pages is not required, though it is still recommended. Additionally, concerns about the flipping side of pages, which are particularly relevant in right-to-left languages like Arabic and Hebrew, do not apply to digital formats.

Even if the digital format is chosen, it is important to remember that clickable elements, such as embedded links, will not function if the document is printed. For this reason, it is advised not to rely on embedded links. Instead, all web links in the reference section, for example, should be written out in full so that they remain accessible and useful in printed form.

- **Well-designed and coherent structure:** The most important aspect of scientific writing is having a well-designed structure. This has been discussed in the chapters before, but in summary: the problem should be introduced first, followed by the literature review, method, results, analysis, conclusion and future directions, and finally, the references. Although there may be slight variations, all scientific works generally follow this structure.

  Clarity and consistency are crucial within each section. Paragraphs should be logically connected, creating a smooth flow that guides the reader from start to finish. To achieve this, it is important to plan each section carefully, avoiding the presentation of unrelated information. The introduction of the work should outline this structure for the reader. A similar approach can be applied to

each chapter or part, with a closing paragraph in the introduction explaining its overall structure.

If not explicitly required, adding section numbers before titles, such as 1.1, 1.2, 1.2.1, and 1.2.2, is not necessary. However, attention should be given to the overall structure. Typically, well-organised work includes four or five levels. If more levels are needed, it may indicate that the current structure is not ideal. Having too many levels can complicate the structure, making it difficult for the reader to follow and potentially disrupting the coherence of the work.

A common mistake in substructure creation is the introduction of a new section with only one subsection. For example, when section 1.3 is divided to include only 1.3.1, the substructure becomes unnecessary. In such

cases, the division is considered ineffective. If only one part is created, indicating that the structure requires revision.

- **Footnotes usage:** Footnotes are used to include additional information that is not directly related to the main topic but still important to mention.[172] This fits new ideas or concepts when being introduced and requires further explanation, but the added text is beyond the scope of the main text. The footnotes are also ideal for citing reference labels, as well as presenting the original names of books or people in their native languages, and to add original texts of quotations.

  However, the length of footnotes should be kept in check. Except for certain works, like historical manuscripts or legal documents, footnotes should generally not exceed 25% of

[172] This is a literary approach of writing called digression.

the page. This is usually enough space for a brief paragraph about the topic. If more extensive information is needed, such as a table or several paragraphs of original text, it is better to use appendices and refer to them in the footnotes.

It is a common mistake to use footnotes for bibliographic information, which should always be included in the references section of the document. Similarly, quotations should be placed in footnotes, not in the references section.

- **Wording**: A key feature of scientific writing is that ideas must be communicated as clearly as possible using the simplest and most precise language. Researchers should avoid using filler words and ensure that the meaning is unambiguous.

  Table 8-1 provides a list of words to avoid and explains why they should be excluded. Note

that this list is not exhaustive and may be expanded.

Table 8-1. words to be avoided in scientific writing

Words	Reason to avoid using
Stuff, things, a lot, good, bad, etc.	Vague or ambiguous
Amazing, beautiful, unbelievable, etc.	Subjective and emotional language
• The experiment did not go as planned; it was a real mess • The new software makes it super easy to crunch numbers and get results fast. • The new method totally blew our minds with its efficiency	Colloquialisms and slang
Best, worst, most, least, etc.	Superlatives
Seems, apparently, probably, etc.	Hedging words

- **Text and Fonts:** It is a common mistake to use multiple fonts when formatting a final document. Only one font should be used throughout the entire document, including in the design of any graphics. The choice of font depends on several factors, including aesthetics, but the most important consideration is its availability. Some fonts are

copyrighted and require a fee or special permission for use.

Publishers or institutions may have specific rules that dictate text size. If no guidelines are provided, care must be taken to avoid text that is too small and difficult to read, or too large, where only a few words fit on a line. It is advisable to print a sample to ensure the text size is appropriate. Different text sizes may be used for titles, but not within the main body of the text. Emphasising ideas by increasing text size should be avoided. The same principle applies to bolding, underlining, and italics, they should be used only when necessary, such as for the first sentence in a list, and not for decorative purposes.

- **Numbers**: All numbers and dates should be written according to a specific system, typically based on guidelines provided by the publisher or institution. If no guidelines are

provided, the author must ensure consistency throughout the document.

Arabic numerals (0, 1, 2, ... 9) are commonly used for writing numbers because they are universally recognised. Roman numerals[173] (I, II, III, ...) can also be used for numbering, but they may become difficult to interpret in longer lists.

For numbers with decimal points, using a period (.) is recommended. While other characters, such as a comma (,), can be used. The most important is the consistency within the document.

[173] A non-positional numeral system, originally developed in the Roman Empire, continued to be used long after the empire's fall. This system uses the Latin alphabet to represent numbers (e.g., V for 5, X for 10, L for 50, C for 100, and M for 1000) and lacks a symbol for zero. Numbers are written using subtractive notation, making them more complex. For example, I represents 1, and IV represents 4. The number 246 is written as CCXLVI, which breaks down to 200 + (50 - 10) + (5 + 1). The system is fully replaced by Arabic numerals.

- **Dates**: The key requirement is maintaining a uniform format throughout the document. Dates should be written using a single calendaring system, with the Gregorian calendar[174] being the preferred choice due to its global recognition. If necessary, equivalent dates in other calendars can be provided in parentheses. For example, August 19, 2024 (Safar 15, 1446H).[175]

  Dates must also be presented in a consistent format, such as (YYYY-MM-DD)[176]. Using numbers only is advisable to prevent confusion, although formats like "21 July 2024" or "21 Jul. 2024" are also acceptable.

[174] A solar calendar introduced by Pope Gregory XIII in 1582 as a reform of the Julian calendar. It is now the most widely used and accepted calendar globally.
[175] Also known as the Islamic or Arabic calendar, this is a lunar calendar used by Muslims to determine religious observances. The calendar consists of 12 lunar months, making up a year of 354 or 355 days. Safar is the second month of the Hijri calendar.
[176] "Y" stands for "year", "M" for "month" and "D" for "day".

- **Acronyms**: Creating an acronym involves forming a new word from the initial letters of each word in a phrase or name. For instance, “UN” stands for the United Nations. The use of acronyms is highly encouraged as they help shorten lengthy scientific terms and make complex sentences easier to read and understand.

  If the document, such as a thesis or book, includes a list of acronyms, all acronyms used should be listed in alphabetical order to make the list searchable. Regardless, the first time an acronym appears in the text, the full name should be written out, followed by the acronym in parentheses. For example, “The United Nations (UN)”.

- **Colouring**: This applies to text, tables, and figures. If colour does not serve a specific purpose, such as helping to differentiate between groups or samples, colouring is not

recommended. Using colour purely for aesthetic reasons introduces subjectivity and can diminish the overall clarity of the work.

When colour is necessary, attention to contrast is crucial. Contrast refers to the difference in colour that makes text, or objects in a figure, visually stand out from their background. For example, blue text on a blue background will create an unreadable solid block because the contrast is zero. Higher contrast improves text readability. That is why a black text on a white background is highly readable.

It is also essential to select colours that are distinguishable for people with colour blindness.[177] For instance, red text on a green background is not readable for those with red-green colour blindness. Similarly, text

[177] Also known as Colour Vision Deficiency (CVD), it is the inability or reduced ability to see colour or distinguish between them under normal lighting conditions.

with low contrast, like light grey on dark grey, can be difficult to read for individuals with other vision impairments.

It is advisable to print samples of coloured items in black and white to ensure that the intended distinctions are still clear. If they are not, adjustments to the contrast should be made. In some cases, using simple patterns can help differentiate objects, even when printed in black and white (Figure 8-1).

- **Figures**: they are an effective way to visually present complex concepts or large datasets, making ideas or comparisons more understandable. However, figures should not be used redundantly or simply to fill space. Instead, they must serve a direct purpose within the context of the work.

  Each figure should have a unique number as an identifier, and every figure must be referenced at least once in the text. In shorter

works, such as academic articles, numbering can start from 1. In longer works, like books with multiple chapters, it is recommended to include the chapter number in the figure label and reset the numbering at the beginning of each chapter. For example, Figure 8-3 indicates the third figure in Chapter 8.

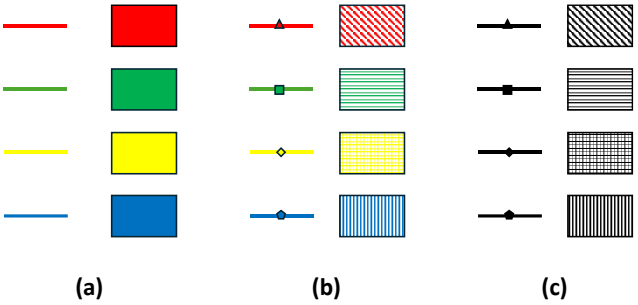


Figure 8-1. Using colours to differentiate lines and areas: (a) Colours only (b) Colours with patterns (c) Colours with patterns when printed in black and white.

Figures should present their information concisely. It is important to avoid overcrowded figures. If necessary, complex figures should be split into multiple simpler ones. The central idea should be the focal

point of the figure, and unnecessary white space should be minimised. Colours and patterns used in figures should be explained in a legend box, and any labels should be consistent in style.

Statistics play a crucial role in science, and they are often easier to understand when presented as graphics rather than tables of numbers. However, there are many different types of statistical graphics, each serving a specific purpose. The challenge is selecting the right chart to best represent the data. Table 8-2 provides an overview of various chart types, their uses, and examples for each.

If the document includes a list of figures, all figures should be listed in ascending order based on their number. The guidelines for fonts and colours mentioned earlier also apply to figures.

Table 8-2. Common types of figures used in statistics, their best uses, and examples

Figure Type	When to use	Example
Histogram	Showing distribution of continuous data, especially for large datasets	Exam scores showing frequency distribution
Pie Chart	Displaying parts of a whole, typically with a small number of categories	Market share of different companies
Bar Chart	Comparing quantities of different categories or tracking changes over time	Sales figures for different months
Line Chart	Displaying trends over time or relationships between variables	Temperature changes over the year
Scatter Plot	Showing relationship between two variables	Height vs. weight for a group of individuals
Heatmap	Visualising data density in two-dimensional space	Website traffic by hour and day of the week

- **Lists**: This structure is used when elements of a group need to be compared in text form. If the order of elements matters, an enumerated list is used. If not, a bullet list is preferred. There are no specific guidelines for

choosing bullet styles, whether black (●), white (○), or other icons, unless explicitly stated. The same applies to enumerated lists, whether using lower-case letters (a, b, c …), upper-case letters (A, B, C …), or Roman numerals (I, II, III). All options are acceptable, but they should be used consistently throughout the document.

Multilevel lists, both enumerated and bulleted, can also be used when list items contain sub-lists, which is common in describing research methods or process with complex structures. Authors should be prepared to handle cases that require three- or four-level lists. As with single-level lists, the main recommendation is to maintain consistency in style. Care should be taken to avoid creating large white spaces due to indentation when using lists.

Types of publication

Although the primary goal of research is to advance human knowledge, not all research publications are designed to serve this end. For example, while academic journal articles aim to share findings with other researchers, popular science books are intended to simplify these findings, making them more accessible and easier to understand for a wider general audience.

Chapter 6 discussed the types of publications that can be cited in research, focusing on how to cite them correctly, particularly the required bibliographical details. Except for website on the Internet,[178] all other types of publications, namely theses, peer-reviewed academic articles, research reports, and popular science books, are considered scientific.

[178] The content of internet websites can be considered scientific, but only if it has undergone a strict peer-review process. However, this is rarely the case, so it is generally safer to assume that the information on a website is not reliable unless there is clear evidence to the contrary.

However, with this similarity shared, they differ in their objectives, structure, and intended audience.

The previously mentioned types of publications will be discussed in detail in the following sections, where their main types and characteristics will be explored. This will be followed by a comparative table outlining key aspects namely: subtypes, target audience, goals, estimated average of both number of pages and the number of references.

Research theses

When a student pursues a post-bachelor's higher education degree, such as research master's degree or a Ph.D., they are required to submit a thesis. This involves completing an entire research project: defining a research problem, building a hypothesis, conducting experiments, collecting and analysing data, and writing a detailed research report, known as a thesis. This thesis is then reviewed by a panel of

experts in the field, and if the research is deemed valid, the student is awarded the degree.[179]

Research master's program[180] typically lasts one or two years, during which students take various courses depending on their specialty. Among these is usually a research method course, where students learn how to conduct research. Toward the end of the program, there is often a dedicated semester focused on practical research, where the student works in a research laboratory, assisting with a project related to their field of study. By the end of this semester, the student must write and defend a thesis before an official jury to earn their diploma.

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[179] Also known as "viva voce" or simply "viva", this term originates from Latin, literally meaning "by word of mouth". It refers to an oral examination in which the candidate defends their thesis or dissertation before a panel of examiners, engaging in a spoken discussion about his research.

[180] There are also Master of Professional Studies (MPS) programs, or simply Professional Master's programs, they focus on developing practical skills for current and aspiring professionals. However, this type of master's program is beyond the scope of this book.

The research master's program is generally where researchers first learn the theory and practice of research. It primarily serves an educational purpose, so the quality of research produced may not always meet the standards of most research institutions. As a result, citations from master's theses are uncommon, though not impossible.

On the other hand, a Ph.D. student typically spends three to five years working on their thesis before submitting it. Unlike the master's degree, there are no learning modules, and the Ph.D. is often treated as a full-time job with a salary. While some teaching responsibilities may be included, the primary focus is on conducting research.

Given the extended time invested in their work and the experience Ph.D. students have when submitting their theses, Ph.D. theses are generally considered more reliable than Master's theses. However, because they are deeply rooted in a specific research subject, Ph.D. theses are considered primary

sources[181] of knowledge. This closeness to the topic can lead to exaggerations, biases, or misinterpretations of the data, so they should be cited with care.

In general, theses are not printed and published for the public when they are to be defended. A few hard copies may be printed for the author and the jury members. The university's library where the thesis was submitted might also request a printed copy for their archives. Some authors later publish their theses as standalone books after reaching an agreement with a publishing house.

A research thesis follows an official structure that is widely accepted, which includes:

1. Title Page
2. Abstract
3. Acknowledgments
4. Table of contents
5. Lists of figures and tables
6. List of abbreviations
7. Content
8. Appendices
9. References

[181] More on primary sources can be found in Chapter 6.

The structure of the title page is determined by each institution, so there is not a universal template. However, most title pages include common elements such as the thesis title, the author's name, the institution and its logos, the department and degree program, the date of submission, and the supervisor's name. Figure 8-2 illustrates a typical title page structure.

The abstract is typically a one-page section that provides a descriptive overview of the thesis, usually covering the objectives, methods, results, and conclusions. The acknowledgments section is optional and allows the author to personally dedicate the work, often to family members or individuals who made significant contributions to the research.

The table of contents, the list of figures and the list tables guide the reader to specific parts of the thesis by referencing page numbers. The table of contents lists the chapters and sections, while the lists of figures and tables refer to the figures and tables, as

their names suggest. If the thesis includes equations, they must be numbered, and a list of equations may be included after the list of tables. The list of abbreviations provides an alphabetical list of acronyms used in the thesis. In some theses, this list may be placed at the end instead of the beginning.

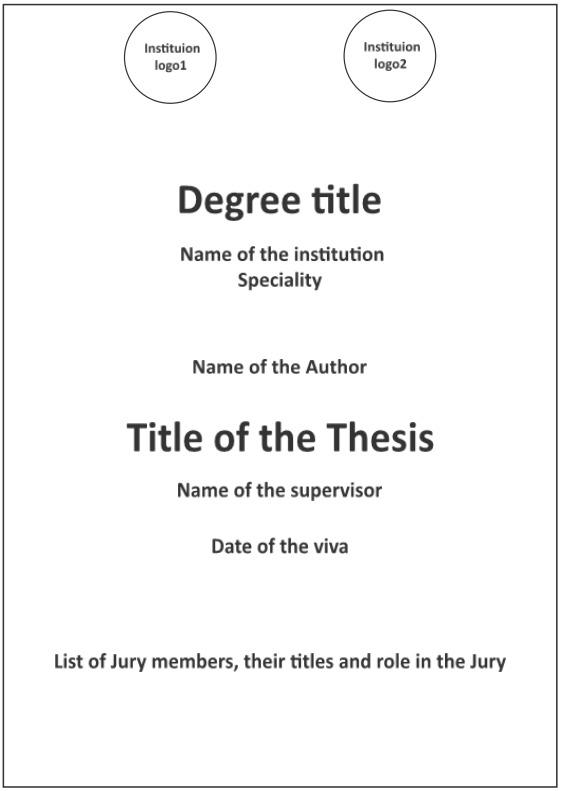

Figure 8-2. Typical thesis title page

The content section typically follows the steps of the research method, with a chapter dedicated to each of the following: an introduction to the research problem, a literature review serving as the state-of-the-art, the research method, the obtained results, the discussion and analysis, and a conclusion summarising the findings and future perspectives.

Finally, the appendices section includes supplementary material such as raw data, questionnaires templates, programming codes, or detailed descriptions of methods used. References are listed at the end, including all sources cited in the thesis.[182] While there is no strict limit on the number of references, the quantity often reflects the depth of the researcher's engagement with the scientific record. Typically, a master's thesis includes

[182] It is a common mistake to put references before appendices. Appendices might include citations, thus, they come before references.

around 50 references, while a Ph.D. thesis may include about 150 or more references.

Academic article

In research, the term “article” or “paper”refers specifically to peer-reviewed written works published in academic journals or conference proceedings. Web articles and opinion pieces in daily newspapers are not considered academic articles, even if the author is a well-known researcher or the topic is research related.

Authors typically pay a fee to participate in conferences or to cover publication costs once their article is accepted by a journal. Therefore, publishing an academic article involves costs, and there is a significant business supports this process.[183]

Academic articles come in various types, which can be classified based on their goal as follows:

[183] The market's total value was estimated at 19 billion dollars in 2020 and has been growing since. For more details, see [WEB21].

- **Abstract**: a 1-2 page article designed to present a new idea is typically referred to as a "brief communication" or "short communication". This type of article usually includes a summary of the idea, the research method to be used, and the anticipated results. It is concise, generally featuring 2-4 references at most. Its primary purpose is to serve as a communication tool during research meetings. The peer-review requirements for this type of article are usually less rigorous compared to other types of research articles.
- **Conference proceedings**: proceedings are a collection of materials presented at a scientific conference, including papers, abstracts, and other content. They serve as a record of the research and discussions that occurred during the event and are usually published as a standalone document, with a

unique ISBN. While peer review process is mandatory for all conferences, the standards may be less stringent compared to journal articles. A typical proceedings article is around 6-8 pages long and includes approximately 20 references.

- **Journal article** It is considered the most reliable source of scientific knowledge due to its rigorous peer-review process, which is stricter compared to other publications. Scientific Journals are released in periodic issues, which are later compiled into volumes.[184] A journal article presents a summary of a complete research study, including a brief overview of the current knowledge, a detailed description of the methods used, and an overview of the results,

[184] Scientific journals are often published at the beginning or end of each quarter, resulting in four issues per year. This is known as a quarterly journal. However, triannual journals, released three times a year, and monthly journals are also frequently chosen formats.

along with analysis and conclusions. On average, a journal article is about 20 pages long and includes around 30-70 references.

- **Survey**: they are journal articles that do not present complete research but instead focus on providing a comprehensive overview of a specific research topic. A survey summarises the current knowledge, highlights key findings and trends, discusses the research methods used, and identifies gaps that still need to be addressed. Due to their broad scope, survey articles usually build on a large number of sources. A typical survey article is usually at least 20 pages long and cites around 100 references.
- **Literature review**: It is a standalone article, or section within a research work, that provides a critical and comprehensive synthesis of existing research on a specific topic. It aims to identify, evaluate, and compare relevant

studies to establish the current state-of-of-art, highlight significant findings, and elucidate theoretical or methodological gaps. Literature reviews serve as a foundation for further research by contextualising the topic within the broader academic discourse and pinpointing areas requiring further investigation. Unlike survey articles, which focus on summarising trends and technical advancements, literature reviews emphasise the interplay of ideas, contrasting methods, and the relative strengths and weaknesses of existing studies.

Chapter 5 provided a detailed discussion of the structure of a typical academic article. Although academic articles can vary greatly in length, they generally, except for abstract articles, adhere to this structure. In summary, a typical academic article includes the title, author information, abstract, keywords, main body, and references. The main body

is usually divided into the introduction, literature review on the addressed problem, methods followed, results obtained, analysis, discussion, and conclusion.

Abstract articles, however, are too brief to follow this structure. Their purpose is to present initial ideas for further discussion, regarding their validity, and to explain potential methods for testing the ideas. At this early stage of research, the research question is often not fully developed, so no tests have been conducted. Therefore, there are no results to discuss. However, an abstract article might include anticipated results or some preliminary measurements to illustrate the proposed method, using a real-world example. In this case, the focus is on the method itself, how the measurements were taken and the rationale for choosing them, rather than on the actual values obtained.

Research report

A research report is a professionally written document that presents the findings of research conducted as part of a larger project or campaign, which can be either public or private. While these reports are considered scientific and prepared by researchers, they are typically intended for an audience outside the research field, such as technicians and stakeholders. The goal is to communicate findings in clear language, emphasising the practical applications of the results.

Research reports can be classified based on their target audience as follows:

- **Academic report**: These are usually written as part of a funded thesis to track progress. When an organisation funds a research program, including Ph.D. theses, one requirement is to provide periodic reports that update on the progress. These reports need to be comprehensible to both academic

reviewers and non-research professionals to assess advancement from both perspectives.

- **Professional report**: Commonly used in private businesses, government agencies, or industry. These reports provide a scientific foundation for specific questions that need answers. The primary purpose of professional research reports is to give decision-makers detailed and accurate information that is understandable and applicable.
- **Technical report**: These reports are designed for engineers or technicians who are using or testing research products. Technical research reports focus on simplifying abstract concepts and offering practical details to assist technicians in modifying or implementing research prototypes.

Although research reports are typically reviewed by researchers before publication, the peer-review process may lack independence. This is because the

reviewers often work within the same institution as the author, which can lead to potential conflicts of interest. As a result, the objectivity and independence of research reports can be a significant concern.

A typical research report has the following key elements:

1. Title page
2. Abstract
3. Table of contents
4. Lists of figures and tables
5. List of abbreviations
6. Content
7. Appendices
8. References

The content element further includes the following section: Introduction, literature review, method, results, discussion and conclusion.

Figure 8-3 shows the title page in a research report, it includes the following elements: logos if the institutions or companies involved, title of the report, report ID, the name of the author(s) and his department, the name of the destination department or agency and the date of publication.

The report ID is an internal identifier assigned according to the administrative numbering system established by the author's institution. The ID helps to easily locate the report within the institution's internal archive system.

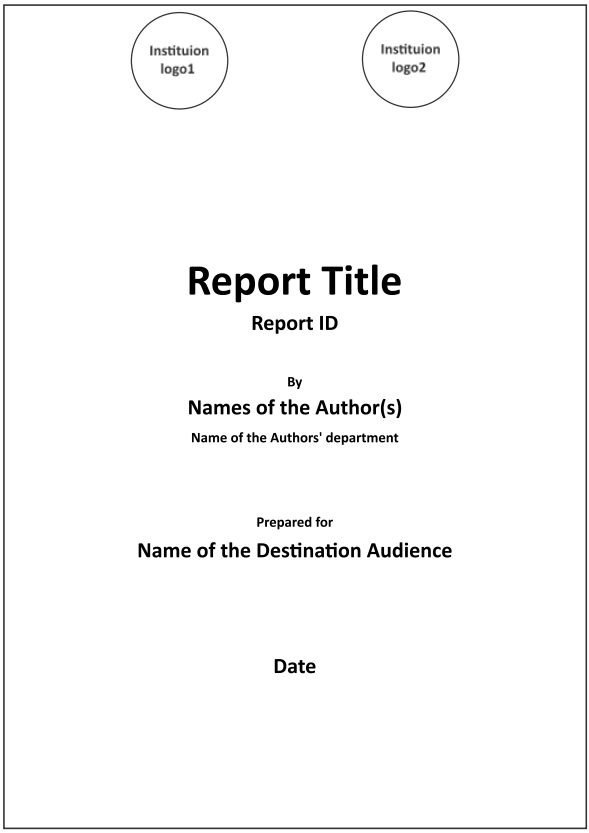

Figure 8-3. Typical research report title page

The structure of a research report is similar to that of a thesis, but with a few key differences:

- **No Acknowledgment Page**: Unlike theses, which are associated with earning an academic degree, research reports are more professional in nature and typically do not include an acknowledgment section.
- **Fewer References**: A Research report contain around 10-40 references typically. A number that is significantly fewer of average number of references in theses. This is because reports focus more on practical aspects and are intended for an audience that is not primarily composed of researchers.
- **Shorter Length**: Research reports are generally shorter in length than Ph.D. theses. A typical research report includes around (50-100) pages, while a typical thesis includes three time the average of the report, with a length of 200 pages in average.

Popular science Book

Books are among the most recognised types of publications, but not all books are suitable for research purposes. In the context of research, the focus is on popular science books. Although these books are written for a general audience, they are authored by experts, scientists, and researchers who aim to simplify complex ideas and make them accessible to those outside the academic field.

Before diving to details, it is essential to distinguish between self-published and traditionally published books. In self-publishing, the author is responsible for every aspect of production, marketing, and distribution, maintaining complete creative control over the content, design, pricing, and rights. In contrast, traditionally published books involve a publisher who may influence content, design, and marketing strategies and often holds rights to certain formats or translations.

Another significant factor to consider is the quality of the work. Traditional publishers employ editors, illustrators, and designers to ensure that the book meets market standards. In contrast, the quality of self-published books can vary widely, depending largely on the author's resources and expertise.

The peer-review process for books is not as rigorous as it is for academic articles. Authors or publishers may ask several reviewers to provide feedback before publication, but there is no guarantee that their suggestions will be implemented. This lack of strict review is why popular science books are generally not considered reliable sources for citation in academic research. Despite this, they remain valuable resources for gaining general knowledge on specific topics.

Unlike research theses and reports, popular science books do not follow a standardised structure. Instead, what defines them as a unique category is their commitment to the scientific method. Authors

have the freedom to present their subjects in various ways: some may build the topic piece by piece, others might start with a broad overview and then break it down, while others might present the material chronologically.

A typical popular science book has the following key elements:

1. Hard cover
2. Inner cover
3. License page
4. Table of contents
5. Lists of figures and tables
6. List of abbreviations
7. Preface
8. Content
9. Appendices
10. Index
11. References

The hardcover is designed to protect the book from excessive wear and tear, often featuring a visually appealing design. Both the hardcover and the inner cover typically display the book's title, the author(s) name(s) and professional titles, the publisher's name, if traditionally published, the edition, if not the first, and the year of publication. The license page provides

bibliographical details, including the book's and author(s) IDs, the legal status of the work, the illustrator's name, the cover designer's name, and the publisher's contact information, such as email and postal address.[185]

The preface of a book acts as an introduction, similar to those found in theses and reports. However, the author has greater freedom to discuss the motivation behind writing the book, the challenges encountered, any changes made from previous editions, if it is not the first, the intended audience, and tips on how to make the most of the book. The preface typically concludes with an acknowledgment section, where the author expresses gratitude to funders, reviewers, editors, and others who contributed to the book.

Authors typically divide the content into chapters, with each chapter focusing on a specific aspect of the topic. There are no strict limits on the length or

[185] Refer to the license page at the beginning of this book for a practical example of what it looks like.

number of chapters, but it is important to maintain a balanced chapter length, usually around 20 to 30 pages. If a book has more than ten chapters, the author might organise them into parts, with each part addressing a specific theme of the studied subject.

If the book becomes too lengthy to be contained in a single volume, it can be split into multiple volumes. However, this is not common, as most popular science books are designed to be compact, portable and user-friendly for marketing purposes. Unlike encyclopaedias, which are often large and span multiple volumes.

The appendices in a popular science book are similar to those found in research theses. The book also features an index, a section not typically included in other scientific publications. The index lists keywords alongside the page numbers where they are mentioned, helping readers locate specific topics or themes without needing to read the entire chapter or book. Keywords can include concepts, important

terms, names of people, places, and more. For each term, the page numbers are listed in ascending order, with each page where the keyword appears noted once in the index, regardless of how many times the term is mentioned on that page.[186]

Citing references is a fundamental aspect of the scientific method, and books are no exception. As in other research publications, the references are listed at the end. There is no specific rule governing the number of references required, but generally, a higher number of citations suggests greater reliability.[187] For instance, a 400-page book might typically cite around 100 references, though this estimate can vary significantly depending on the content and depth of the work.

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[186] Refer to the index at the end of this book for a practical example of what an index looks like.

[187] If a book lacks a reference section or has a very brief one, it cannot be considered scientific. For instance, educational books used in primary schools often simplify scientific topics for teaching purposes. These books are strictly educational and do not qualify as scientific works.

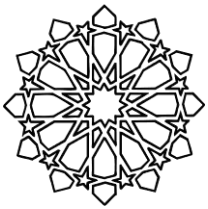
Table 8-3 shows key aspects of research publications namely: subtypes, target audience, goals, estimated average of both number of pages,[188] and the number of references.

[188] The numbers provided are estimates of the expected average. However, there are situations where this guideline may not apply, resulting in the actual number of pages being either lower or higher than the values shown in the table.

Table 8-3. Comparison of different types of scientific publications

Types		Audience	Goal	#. pages	#. ref
Thesis	**Mast.**	-	• Obtain Master's degrees • Learn how to conduct a research	75-100	~ 50
	Ph.D.	Peer researchers	• Obtain Ph.D. • Test new ideas or hypotheses	150-250	~ 150
Academic article	**Abs.**	Peer researchers	Provide brief descriptions of original research	1-2	~ 4
	Conf.		Share Initial findings	6-8	~ 20
	Jour.		Share final results	10-20	~ 30-70
	Surv.		overview of a subject (technical details, history of discoveries etc. …)	+20	+100
	Lit. rev.		all relevant works on the subject	+20	+100

Report	**Acad.**	Peer researchers, or stakeholders	provide a way to follow the advancement in a research project	50 - 150	~10 - 40
	Prof.	Decision-makers	Provide Scientific basis		
	Tech.	Technical engineers	• Explain abstract concept • Provide technical details on a research prototype		
Book		Public audience	Popularise science	300 - 500	+100



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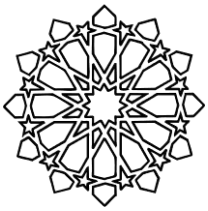

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Michel BAKNI received the B.S. degree in telecommunication and electronics from Tishreen University, Syria, in 2013 and the M.S. degree from UTBM (French: Université de Technologie de Belfort-Montbéliard), France, in 2017, in mobile and distributed networks. In 2021, He received a Ph.D. degree in electronics from the doctoral school of the University of Bordeaux. His research interests include networking, wireless sensor networks, and energy consumption optimisation.

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  - بروتوكول الإنترنت: الإصداران الرابع والسادس (ISBN: 978-2-95-76887-1-5)
- In English:
  - Huawei HCIA-IoT v. 2.5: Evaluation Questions (DOI: 10.6084/m9.figshare.14336687)

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